IMPINGEMENT LOSSES AT THE D. C. COOK NUCLEAR PLANT DURING 1975-1979 WITH A DISCUSSION OF FACTORS RESPONSIBLE AND RELATIONSHIPS TO FIELD CATCHES

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INTRODUCTION

The Donald C. Cook Nuclear Plant is a 2,200 MW utility on the southeastern shore of Lake Michigan near Bridgman, Michigan. Unit 1 (1,100 MW), which began operation in 1975, requires 2.7 x 10^6 liters/min cooling water, while Unit 2, also 1,100 MW, uses 3.6 x 10^6 liters/min. Though Unit 2 began operation in 1978, sustained pumping for a month or longer at full capacity did not occur until 1979. Cooling water enters through three intake cribs located 686 m offshore in 7.3 m of water, and heated water (with a calculated maximum ΔT of 21°C) is discharged through two slot-jet discharge structures located 366 m offshore in 5.5 m of water. With two units operating, water velocity at the intake crib is 0.4 m/s. Maximum water velocity is 1.8 m/s within the intake pipe. To prevent erosion and scour, a riprap bed (approximately 6 ha) of crushed limestone 0.1-1.0 m in diameter was deposited around the intake and discharge structures during plant construction.

Within the screenhouse, trash bars 6.6 cm apart prevent large debris from entering the forebay. Within the forebay, vertical traveling screens impinge trash and fish too large to pass through the 9.5-mm-mesh screens. Smaller organisms (mostly fish fry, larvae and eggs, and zooplankton) are entrained with the cooling water and pass through the condensers. In addition to the terms "impingement" and "entrainment," "entrapment" in this report refers to fish entering the forebay through the intakes. Impingement is distinguished from entrapment because of the possibility that not all fish which enter the forebay are eventually impinged.

This report contains annual estimates of impingement losses for the Cook Plant and species composition of impinged fish and compares them with compo-

sition of field-caught fish for 1975-1979. Also discussed are seasonal and yearly trends in fish abundance, environmental and plant operation effects on rates of fish impingement, and possible effects of high impingement rates on local abundance of certain fish species.

METHODS

Fish and debris collected from the traveling screens were separated by Cook Plant personnel. All fish were bagged, labeled with date and time, and then frozen. University of Michigan personnel collected and weighed all frozen fish; a 24-h sample was saved every fourth day and sorted by species and size. When many fish of the same size were collected in fourth-day samples, a subsample of up to 30 fish was randomly selected and the remaining fish were weighed and discarded. All saved fish were measured to the nearest mm (total length), weighed to the nearest g, sexed, and examined for presence of food, condition of gonads, presence of disease, or physical damage.

Both fourth-day samples (number and weight of fish) and weight of fish impinged on interim days were used to estimate total monthly impingement by species. Percent species composition by weight of fourth-day samples was used to partition the actual monthly weight of fish impinged into weight estimates by species, according to the formula:

$$E_w = (S_w/P_w)T_w$$

where:

E_w = Estimated monthly weight of fish impinged for a given species;

S_w = Monthly weight of fourth-day impingement samples, for a given species;

P_w = Monthly weight of fourth-day impingement samples, all fish combined;

T_w = Total monthly weight of all fish impinged (includes fourth-day and interim samples).

Number of fish impinged per month was then estimated using:

$$E_n = E_w/\overline{W}$$

where:

E_n = Estimated total number of fish impinged each month for a given species;

$\overline{W}$ = Mean weight per fish of a given species, calculated for each species from number and weight of fish of each species impinged in fourth-day samples for a given month.

Offshore standard-series field samples were collected by gill net and bottom trawl from four stations: 6- and 9-m stations at the Cook Plant and 6- and 9-m stations at Warren Dunes State Park, about 11 km south of the Cook Plant. Fish were seined from the beach zone at two stations north and south of the Cook Plant, and one station at Warren Dunes State Park.

Gill nets 160 x 1.8 m were set at offshore stations once per month for approximately 12 h during daylight and 12 h during the night. Catch was adjusted to catch per 12 h to standardize data. Nets were composed of 12 panels of netting as follows: 7.6-m sections of each of the following mesh sizes (bar measure) - 1.3 cm, 1.9 cm, and 2.5 cm; 15.2-m sections of mesh sizes 3.2-7.6 cm by 0.6-cm intervals; and a final 15.2-m section of 10-cm mesh. All gill nets were set parallel to shore on the bottom.

Duplicate, 10-min bottom tows were taken monthly both day and night at offshore stations, using a semi-balloon, nylon trawl having a 4.9-m headrope and a 5.8-m footrope. The body and cod end were composed respectively of 1.9-cm and

1.6-cm bar mesh, while the cod end interliner was 0.7-cm bar mesh. All trawl hauls were made at an average speed of 5 km/h, i.e., at a fixed rpm using the University of Michigan's R/V MYSIS. The trawl was towed parallel to shore following the 6- and 9-m depth contours; one replicate was taken north to south and the other south to north.

Beach seining was usually conducted during periods of reduced wave height using a nylon seine 38 x 1.8 m with a 1.8 x 1.8 x 1.8-m bag; the entire seine had 0.64-cm bar mesh. The seine was first stretched perpendicular to the shoreline and then pulled parallel to shore a distance of 61 m. Duplicate, non-overlapping samples were taken in this manner both day and night once each month at beach stations. The seine was pulled against the current or southerly when no current was detectable. When the current was too strong to seine against, seining was done with the current.

Field-caught fish were processed in the same manner as impinged fish. For a more detailed discussion of field-sampling methods, see Jude et al. (1979). Common and scientific names of fish discussed in this paper are presented in Table 1.

RESULTS AND DISCUSSION

Species Composition

The number of fish impinged annually at the Cook Plant ranged from 64,279 fish in 1977 to 615,397 fish in 1978 (Tables 2-6). When numbers of fish impinged of each species were totaled for 1975-1979, the most abundant fish was alewife (57% of total catch). Following in order of abundance were spottail shiner (17%), trout-perch (9%), yellow perch (7%), rainbow smelt (6%), bloater (2%), and slimy sculpin (1%). None of the miscellaneous species ever constituted more than 0.9% of the total number of fish impinged over 1975-1979 or

Table 1. Common and scientific names (Robins et al. 1980) of field-caught and impinged fish species collected during 1975 at the Cook Plant, southeastern Lake Michigan.

Common Name	Scientific Name	Common Name	Scientific Name
Alewife	*Alosa pseudoharengus*	Lake whitefish	*Coregonus clupeaformis*
Black bullhead	*Ictalurus melas*	Largemouth bass	*Micropterus salmoides*
Black crappie	*Pomoxis nigromaculatus*	Logperch	*Percina caprodes*
Bloater	*Coregonus hoyi*	Longnose dace	*Rhinichthys cataractae*
Bluegill	*Lepomis macrochirus*	Longnose sucker	*Catostomus catostomus*
Brown bullhead	*Ictalurus nebulosus*	Mottled sculpin	*Cottus bairdi*
Brown trout	*Salmo trutta*	Ninespine stickleback	*Pungitius pungitius*
Burbot	*Lota lota*	Northern pike	*Esox lucius*
Central mudminnow	*Umbra limi*	Pirate perch	*Aphredoderus sayanus*
Channel catfish	*Ictalurus punctatus*	Pumpkinseed	*Lepomis gibbosus*
Chestnut lamprey	*Ichthyomyzon castaneus*	Quillback	*Carpiodes cyprinus*
Chinook salmon	*Oncorhynchus tschawytscha*	Rainbow smelt	*Osmerus mordax*
Coho salmon	*Oncorhynchus kisutch*	Rainbow trout	*Salmo gairdneri*
Common carp	*Cyprinus carpio*	Rock bass	*Ambloplites rupestris*
Deepwater sculpin	*Myoxocephalus thompsoni*	Sea lamprey	*Petromyzon marinus*
Emerald shiner	*Notropis atherinoides*	Shorthead redhorse	*Moxostoma macrolepidotum*
Freshwater drum	*Aplodinotus grunniens*	Silver redhorse	*Moxostoma anisurum*
Gizzard shad	*Dorosoma cepedianum*	Slimy sculpin	*Cottus cognatus*
Golden shiner	*Notemigonus crysoleucas*	Smallmouth bass	*Micropterus dolomieui*
Goldfish	*Carassius auratus*	Spottail shiner	*Notropis hudsonius*
Grass pickerel	*Esox americanus vermiculatus*	Spotted sucker	*Minytrema melanops*
Green sunfish	*Lepomis cyanellus*	Tadpole madtom	*Noturus gyrinus*
Johnny darter	*Etheostoma nigrum*	Trout-perch	*Percopsis omiscomaycus*
Lake chub	*Couesius plumbeus*	White crappie	*Pomoxis annularis*
Lake chubsucker	*Erimyzon sucetta*	White sucker	*Catostomus commersoni*
Lake trout	*Salvelinus namaycush*	Yellow bullhead	*Ictalurus natalis*
		Yellow perch	*Perca flavescens*

Table 2. Number of fish impinged on Cook Plant traveling screens during 1975. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	193	1	1620	48997	22811	81840	11230	1910	458	2533	1016	1732	174341	77.58
Trout-perch	7	10	22	120	261	376	129	107	517	7327	5620	877	15373	6.84
Yellow perch	228	154	245	1195	45	313	400	492	414	4539	1816	2165	12006	5.34
Spottail shiner	86	261	345	961	748	701	117	44	318	1880	1980	2544	9985	4.44
Slimy sculpin	116	120	340	2959	1494	1171	436	321	357	261	294	267	8136	3.62
Rainbow smelt	8	11	75	873	1042	158	49	229	39	842	198	222	3746	1.67
Gizzard shad	1	13	10	33	0	0	0	0	0	4	64	153	278	0.12
Ninespine stickleback	1	0	9	69	86	20	2	0	1	3	0	3	194	0.09
Johnny darter	1	0	0	1	30	90	17	16	11	2	10	2	180	0.08
Lake trout	4	0	1	39	4	7	5	0	1	0	17	23	101	0.04
Channel catfish	16	4	10	12	0	3	1	1	1	0	0	2	50	0.02
Bloater	0	0	2	5	2	4	9	5	6	9	5	2	49	0.02
Bluegill	0	0	0	6	6	5	1	1	2	0	9	18	48	0.02
Burbot	2	1	3	5	4	6	1	4	2	4	2	3	37	0.02
Black bullhead	6	1	4	12	9	0	0	1	0	1	0	1	35	0.02
Longnose sucker	0	1	0	2	2	6	1	4	1	2	4	0	23	0.01
Pumpkinseed	0	0	0	0	0	1	0	0	0	2	4	16	23	0.01
White sucker	0	0	1	2	3	7	1	0	1	0	0	1	16	0.01
Largemouth bass	0	0	0	0	0	0	0	2	2	1	1	7	13	0.01
Green sunfish	0	0	0	0	0	0	0	0	0	1	1	11	13	0.01
Black crappie	0	0	0	0	0	0	0	0	0	1	2	8	11	<0.01
Central mudminnow	1	2	2	2	0	0	0	0	0	0	1	1	9	<0.01
Coho salmon	0	0	0	3	4	0	0	0	0	0	0	1	8	<0.01
Chinook salmon	0	0	0	3	0	0	3	1	0	0	0	0	7	<0.01
White crappie	1	0	0	0	0	0	0	0	0	1	0	4	6	<0.01
Longnose dace	0	0	0	1	0	0	0	0	0	1	4	0	6	<0.01
Golden shiner	0	0	1	3	0	0	0	0	0	0	1	0	5	<0.01
Smallmouth bass	1	0	0	0	0	0	0	0	2	0	1	1	5	<0.01
Yellow bullhead	0	1	0	0	0	0	0	0	0	0	3	1	5	<0.01
Rainbow trout	0	1	0	0	0	1	0	1	0	0	0	1	4	<0.01
Chestnut lamprey	0	0	0	2	1	0	0	1	0	0	0	0	4	<0.01
Northern pike	0	0	0	1	1	0	0	1	0	0	0	0	3	<0.01
Rock bass	0	0	0	2	0	0	0	0	0	0	1	0	3	<0.01
Common carp	0	0	0	0	0	0	0	2	0	0	0	0	2	<0.01
Goldfish	0	0	0	1	1	0	0	0	0	0	0	0	2	<0.01
Quillback	0	1	0	0	0	0	0	0	0	0	1	0	2	<0.01
Hybrid sunfish	0	0	1	0	0	0	0	0	0	0	0	0	1	<0.01
Emerald shiner	0	0	1	0	0	0	0	0	0	0	0	0	1	<0.01
Deepwater sculpin	0	0	0	1	0	0	0	0	0	0	0	0	1	<0.01
Lake whitefish	0	0	0	1	0	0	0	0	0	0	0	0	1	<0.01
Spotted sucker	0	0	0	0	0	0	0	0	0	0	0	1	1	<0.01
Pirate perch	0	0	0	1	0	0	0	0	0	0	0	0	1	<0.01
Logperch	0	0	0	0	1	0	0	0	0	0	0	0	1	<0.01
Totals	672	582	2692	55312	26555	84709	12402	3143	2133	17414	11055	8067	224736	

Table 3. Estimated number of fish impinged on Cook Plant traveling screens during 1976. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	186	3	7748	5823	6603	31584	38813	9579	3373	2348	8644	254	114958	62.54
Spottail shiner	2330	1872	5602	2659	655	188	590	684	1702	2938	2152	2732	24104	13.11
Yellow perch	1663	111	221	438	277	331	2796	3840	5549	4106	198	1779	21309	11.59
Trout-perch	145	34	82	22	788	282	2871	1335	3843	679	155	121	10357	5.63
Slimy sculpin	252	106	494	2996	1667	290	376	452	368	150	112	139	7402	4.03
Rainbow smelt	240	75	197	808	569	45	268	210	8	116	86	150	2772	1.51
Gizzard shad	1161	72	63	0	0	0	0	0	8	27	310	139	1780	0.97
Johnny darter	0	1	0	22	129	15	32	11	94	19	17	6	346	0.19
Lake trout	8	10	30	0	24	11	0	0	0	0	9	23	115	0.06
Ninespine stickleback	5	3	6	0	72	0	0	0	0	4	17	0	107	0.06
Burbot	5	7	7	11	5	4	5	0	8	0	17	6	75	0.04
Channel catfish	22	12	11	0	0	4	0	0	0	4	0	17	70	0.04
Bloater	7	0	2	0	10	0	27	0	0	8	9	0	63	0.03
Black bullhead	2	1	7	11	5	0	0	0	0	4	9	6	45	0.02
Longnose sucker	2	4	4	11	0	0	0	22	0	0	0	0	43	0.02
Brown trout	0	0	0	11	5	0	0	0	0	0	9	12	37	0.02
Pumpkinseed	2	2	4	0	0	0	0	0	0	15	9	0	32	0.02
White sucker	4	2	0	0	0	8	5	0	8	0	0	0	27	0.01
Bluegill	2	0	0	0	0	4	0	0	0	8	9	0	23	0.01
Coho salmon	1	2	4	0	0	0	0	0	0	0	9	6	22	0.01
Smallmouth bass	0	0	0	0	0	0	0	0	0	0	9	12	21	0.01
Rainbow trout	0	1	0	0	5	0	5	0	0	0	0	6	17	0.01
Northern pike	2	0	0	0	0	4	0	11	0	0	0	0	17	0.01
Chinook salmon	0	0	2	0	10	4	0	0	0	0	0	0	16	0.01
Central mudminnow	0	0	9	0	0	0	0	0	0	0	0	0	9	<0.01
Longnose dace	3	1	0	0	0	0	0	0	0	4	0	0	8	<0.01
Green sunfish	2	0	0	0	0	4	0	0	0	0	0	0	6	<0.01
Common carp	4	0	2	0	0	0	0	0	0	0	0	0	6	<0.01
Deepwater sculpin	0	0	0	0	5	0	0	0	0	0	0	0	5	<0.01
Lake chub	0	1	0	0	0	0	0	0	4	0	0	0	5	<0.01
Tadpole madtom	0	0	0	0	0	0	5	0	0	0	0	0	5	<0.01
Black crappie	2	0	2	0	0	0	0	0	0	0	0	0	4	<0.01
Largemouth bass	0	0	0	0	0	0	0	0	4	0	0	0	4	<0.01
Hybrid sunfish	0	0	4	0	0	0	0	0	0	0	0	0	4	<0.01
Grass pickerel	0	1	0	0	0	0	0	0	0	0	0	0	1	<0.01
Yellow bullhead	0	1	0	0	0	0	0	0	0	0	0	0	1	<0.01
Rock bass	0	1	0	0	0	0	0	0	0	0	0	0	1	<0.01
Totals	6050	2323	14501	12812	10829	32778	45793	16144	14969	10430	11780	5408	183817	

Table 4. Estimated number of fish impinged on Cook Plant traveling screens during 1977. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	7	0	512	2516	3892	15816	1629	219	888	5323	194	502	31498	59.22
Yellow perch	10	48	1045	606	51	184	3592	329	144	463	272	451	7195	13.53
Spottail shiner	4	41	1990	1507	220	71	303	37	69	408	147	235	5032	9.46
Trout-perch	1	8	24	141	46	226	1202	119	208	2625	118	108	4826	9.07
Slimy sculpin	6	3	184	1323	363	205	45	9	29	29	13	23	2232	4.20
Rainbow smelt	8	41	112	291	113	120	306	9	17	385	36	50	1488	2.80
Bloater	0	1	0	0	0	14	13	0	0	239	8	27	302	0.57
Lake trout	5	1	8	10	15	0	0	0	0	7	27	42	115	0.22
Johnny darter	0	0	0	15	51	28	5	0	0	4	0	0	103	0.19
Ninespine stickleback	1	0	8	39	36	7	0	0	0	4	0	0	95	0.18
Burbot	0	1	0	0	10	14	5	9	6	0	6	0	51	0.10
Gizzard shad	5	0	0	0	0	0	0	0	0	11	11	8	35	0.07
Channel catfish	7	4	12	0	0	0	0	0	0	4	0	0	27	0.05
Brown trout	9	3	0	10	0	0	0	0	0	0	2	0	24	0.05
Coho salmon	2	1	4	5	0	0	0	0	0	0	2	8	22	0.04
Longnose sucker	0	0	0	0	0	0	20	0	0	0	0	0	20	0.04
Longnose dace	0	0	0	0	0	0	0	0	0	4	0	15	19	0.04
Black bullhead	0	0	16	0	0	0	0	0	0	0	0	0	16	0.03
Mottled sculpin	0	0	0	0	0	0	0	0	0	0	2	12	14	0.03
White sucker	0	0	0	0	0	0	0	0	6	0	4	4	14	0.03
Smallmouth bass	0	0	4	0	0	0	0	0	0	0	2	4	10	0.02
Bluegill	0	0	0	0	0	0	0	0	0	0	2	8	10	0.02
Largemouth bass	1	0	0	0	0	0	3	0	0	4	0	0	8	0.02
Black crappie	0	0	0	0	0	0	0	0	0	7	0	0	7	0.01
Lake chub	0	0	0	0	0	0	0	0	0	0	2	4	6	0.01
Shorthead redhorse	0	1	0	0	0	0	0	0	0	0	0	4	5	0.01
Lake chubsucker	0	0	4	0	0	0	0	0	0	0	0	0	4	0.01
Green sunfish	0	0	4	0	0	0	0	0	0	0	0	0	4	0.01
Rock bass	0	0	0	0	0	0	0	0	0	4	0	0	4	0.01
Pumpkinseed	0	0	0	0	0	0	0	0	0	0	2	0	2	<0.01
Yellow bullhead	2	0	0	0	0	0	0	0	0	0	0	0	2	<0.01
Totals	68	153	3927	6463	4797	16685	7123	731	1367	9521	850	1505	53190	

Table 5. Estimated number of fish impinged on Cook Plant traveling screens during 1978. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	0	0	8	4438	52824	156016	10447	4140	6154	2687	1419	238133	38.70
Spottail shiner	4204	145	959	2256	610	1147	149282	6639	5360	5031	496	1880	178009	28.93
Trout-perch	170	5	35	19	477	1319	79256	2835	2163	2235	33	145	88692	14.41
Rainbow smelt	170	15	1118	55	3432	1096	27865	16468	675	51	0	68	51013	8.29
Yellow perch	795	26	363	343	57	236	20532	5254	1950	607	2404	244	32811	5.33
Bloater	6	0	0	0	0	38	21981	767	18	138	33	104	23085	3.75
Slimy sculpin	50	11	22	131	415	57	132	42	18	20	0	136	1034	0.17
Gizzard shad	19	0	3	0	0	0	6	0	0	225	82	357	692	0.11
Mottled sculpin	88	5	3	0	33	19	6	23	92	51	0	72	392	0.06
Ninespine stickleback	13	0	48	5	138	51	19	5	0	0	0	9	288	0.05
Lake trout	0	7	10	3	10	6	0	5	9	36	71	86	243	0.04
White sucker	6	0	3	0	5	0	32	19	0	107	0	14	186	0.03
Longnose sucker	19	4	13	14	5	32	25	5	18	10	11	9	165	0.03
Burbot	6	7	13	8	5	0	6	14	9	31	0	9	108	0.02
Johnny darter	0	0	3	0	10	19	57	19	0	0	0	0	108	0.02
Coho salmon	6	5	19	14	10	6	13	0	0	5	0	0	78	0.01
Brown trout	6	2	3	0	0	0	0	0	9	0	0	41	61	0.01
Chinook salmon	0	0	0	3	0	6	13	0	0	0	5	32	59	0.01
Longnose dace	25	0	0	0	0	0	0	0	0	0	0	18	43	0.01
Shorthead redhorse	0	0	3	0	0	0	0	0	0	0	0	27	30	<0.01
Channel catfish	13	0	0	3	0	0	0	0	0	10	0	0	26	<0.01
Freshwater drum	0	0	0	0	0	0	0	0	18	0	0	0	18	<0.01
Pumpkinseed	0	0	0	0	0	0	6	0	9	0	0	0	15	<0.01
Black bullhead	0	0	0	3	0	0	0	0	0	0	0	9	12	<0.01
White crappie	0	0	0	0	0	0	6	0	0	5	0	0	11	<0.01
Bluegill	0	0	0	0	0	0	6	0	0	5	0	0	11	<0.01
Brown bullhead	0	0	0	0	0	6	0	0	0	0	0	5	11	<0.01
Rock bass	6	2	0	0	0	0	0	0	0	0	0	0	8	<0.01
Rainbow trout	0	0	6	0	0	0	0	0	0	0	0	0	6	<0.01
Lake chub	6	0	0	0	0	0	0	0	0	0	0	0	6	<0.01
Green sunfish	0	0	0	0	0	0	6	0	0	0	0	0	6	<0.01
Chestnut lamprey	0	0	0	0	0	0	0	0	0	0	0	5	5	<0.01
Common carp	0	0	0	0	0	0	0	0	0	0	0	5	5	<0.01
Silver redhorse	0	0	0	0	0	0	0	0	0	5	0	0	5	<0.01
Northern pike	0	0	0	0	0	0	0	0	0	0	0	5	5	<0.01
Emerald shiner	0	0	0	0	0	0	0	0	0	0	0	5	5	<0.01
Smallmouth bass	0	0	0	3	0	0	0	0	0	0	0	0	3	<0.01
Black crappie	0	2	0	0	0	0	0	0	0	0	0	0	2	<0.01
Totals	5608	236	2624	2868	9645	56862	455265	42542	14488	14726	5822	4704	615390	

Table 6. Estimated number of fish impinged on Cook Plant traveling screens during 1979. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	10	0	5	871	18	82	108157	62215	154201	3178	42	1930	330709	68.79
Spottail shiner	5176	347	676	8956	25	0	3630	9845	14007	9840	72	187	52761	10.97
Yellow perch	1315	184	585	308	14	0	580	4094	29843	1271	20	135	38349	7.98
Rainbow smelt	382	33	463	3317	11	0	6363	7978	16158	657	5	31	35398	7.36
Trout-perch	314	43	36	271	4	0	3580	3808	3439	3432	28	47	15002	3.12
Slimy sculpin	152	49	249	1788	18	0	151	105	16	42	0	52	2622	0.55
Bloater	31	0	5	0	0	0	2244	45	59	64	3	5	2456	0.51
Chinook salmon	10	11	631	21	0	0	7	45	4	0	0	0	729	0.15
Burbot	231	65	127	38	22	0	18	15	14	42	3	0	575	0.12
Mottled sculpin	183	22	10	0	0	0	29	196	20	53	3	16	532	0.11
Lake trout	37	16	0	0	4	0	0	45	14	106	18	42	282	0.06
White sucker	52	38	51	33	7	20	4	45	0	21	0	0	271	0.06
Gizzard shad	47	5	5	0	0	0	0	15	4	138	2	36	252	0.05
Longnose sucker	16	11	51	29	11	0	18	30	5	32	7	0	210	0.04
Coho salmon	16	0	81	54	14	0	0	0	0	0	0	0	165	0.03
Brown trout	26	16	36	17	0	0	0	0	0	0	0	0	95	0.02
Shorthead redhorse	37	16	15	0	0	0	0	0	0	0	0	0	68	0.01
Ninespine stickleback	10	0	5	46	0	0	4	0	0	0	0	0	65	0.01
Johnny darter	0	0	0	0	0	0	7	45	7	0	0	0	59	0.01
Channel catfish	21	11	5	8	0	0	0	0	5	0	0	0	50	0.01
Common carp	0	0	15	0	4	0	0	15	0	0	0	0	34	0.01
Rainbow trout	0	0	10	4	0	0	0	0	0	0	0	0	14	<0.01
Silver redhorse	0	0	0	0	0	0	0	0	0	11	0	0	11	<0.01
Largemouth bass	0	0	0	0	0	0	0	0	0	11	0	0	11	<0.01
Lake whitefish	5	0	5	0	0	0	0	0	0	0	0	0	10	<0.01
Goldfish	0	5	0	0	0	0	0	0	0	0	0	0	5	<0.01
Central mudminnow	0	0	5	0	0	0	0	0	0	0	0	0	5	<0.01
Sea lamprey	0	0	5	0	0	0	0	0	0	0	0	0	5	<0.01
Smallmouth bass	0	0	5	0	0	0	0	0	0	0	0	0	5	<0.01
Black crappie	5	0	0	0	0	0	0	0	0	0	0	0	5	<0.01
Rock bass	0	0	5	0	0	0	0	0	0	0	0	0	5	<0.01
Lake chubsucker	0	0	0	4	0	0	0	0	0	0	0	0	4	<0.01
Black bullhead	0	0	0	4	0	0	0	0	0	0	0	0	4	<0.01
Brown bullhead	0	0	0	4	0	0	0	0	0	0	0	0	4	<0.01
White crappie	0	0	0	0	0	0	0	0	2	0	0	0	2	<0.01
Freshwater drum	0	0	0	0	0	0	0	0	2	0	0	0	2	<0.01
Totals	8076	872	3086	15773	152	102	124792	88541	217800	18898	203	2481	480776	

of the total for any 1 yr (Tables 2-6). Except for alewife, which was always the most abundant species, ranks of the other species varied from year to year. In making comparisons among years, note that both units were operating during 1978 and 1979, so these years should be considered separately from 1975-1977.

Compared to other years, fish impingement was exceptionally low during 1977 for the five most abundant species, but most dramatically for alewives. Alewives showed a marked decrease in number of adults impinged in June-August, a pattern which was also true for rainbow smelt but was not as clear for spottail shiner, trout-perch, or yellow perch. It is not at all clear why 1977 was such an exceptional year. Number of fish impinged in 1977 did not correlate with abundance in field catches, which were relatively high (Appendixes 1-5); the plant was operating at full capacity during the months when fish were most abundant inshore (Table 7); and inshore water temperatures and patterns of upwelling were not unusual during 1977 (Appendixes 6-10).

Slimy sculpin was most abundant in impingement samples in 1975 and 1976. Because sculpin colonize the riprap in preference to nearby sand (Dorr and Jude 1980), high impingement rates during 1975 and 1976 may have resulted from rapid colonization during these years. Stabilization of the sculpin population after 1976 may have resulted in fewer sculpin being impinged.

Few bloaters were impinged in 1975 (49 fish) and 1976 (63 fish), while over 500 were impinged in 1977 and over 23,000 in 1978. Increased impingement of this species apparently reflected an increase in the lake-wide bloater population, as was indicated by our field catches and those of others (Crowder et al. 1981).

Table 7. Monthly water volume (in millions of cubic meters) pumped through the condenser circulating water system of the Cook Plant, southeastern Lake Michigan from 1975 to 1979. Unit 1 was operational since January 1975, Unit 2 since February 1978.

Month	1975	1976	1977	1978	1979
January	64.9	85.7	24.9	114.4	273.2
February	75.6	88.5	54.5	121.6	275.2
March	117.7	103.6	118.7	207.1	281.9
April	121.0	76.2	114.5	115.9	173.7
May	125.8	86.0	97.4	90.4	100.5
June	122.8	122.7	93.5	194.4	33.3
July	81.7	120.5	103.6	224.5	227.7
August	128.7	130.5	123.3	249.6	324.6
September	125.2	109.0	97.7	277.6	314.3
October	132.2	137.9	112.4	298.8	245.9
November	90.6	126.2	76.3	202.8	107.3
December	111.6	105.1	120.9	272.5	118.0
Annual total	1298.	1292.	1138.	2370.	2476.

During 1975-1979, 53 species were impinged. Twenty species were impinged every year for all 5 yr of the study (Table 8), while 17 species were impinged 2 years or less and were considered rare.

Seasonal Abundance

Number of fish impinged per month at the Cook Plant varied seasonally (Tables 2-6). Most fish were impinged April through October; few were impinged during winter. Each year (1975-1979) was characterized by a month of peak impingement during June or July; often a secondary peak in October; and in 1975 and 1979, a secondary peak in April.

In 1975, fish impinged in April were 89% alewives and 5% slimy sculpins by number; in 1979 fish impinged in April were 57% spottail shiners, 21% rainbow smelt, and 11% slimy sculpin. Warming of inshore water during April of both 1975 and 1979 was characterized by a narrow band of warmer water within 2 km of shore, which was separate and distinct from colder, offshore water. Fish seeking warm water may have congregated within this narrow band. High fish im-

Table 8. Frequency of occurence by year of fish species impinged at the Cook Plant, southeastern Lake Michigan, 1975-1979.

5 years	4 years	3 years	2 years	1 year
Alewife	Bluegill	Central mudminnow	Brown bullhead	Golden shiner
Black bullhead	Brown trout	Lake chub	Chestnut lamprey	Grass pickerel
Black crappie	Common carp	Mottled sculpin	Deepwater sculpin	Logperch
Bloater	Chinook salmon	Northern pike	Emerald shiner	Pirate perch
Burbot	Green sunfish	Shorthead redhorse	Freshwater drum	Quillback
Channel catfish	Largemouth bass	White crappie	Goldfish	Sea lamprey
Coho salmon	Longnose dace	Yellow bullhead	Lake chubsucker	Spotted sucker
Gizzard shad	Pumpkinseed		Lake whitefish	Tadpole madtom
Johnny darter	Rainbow trout		Silver redhorse	
Lake trout				
Longnose sucker				
Ninespine stickleback				
Rainbow smelt				
Rock bass				
Slimy sculpin				
Smallmouth bass				
Spottail shiner				
Trout-perch				
White sucker				
Yellow perch				

pingement rates during this time may have resulted from increased activity and movement of fish, and higher densities of fish inshore.

Over 80% of the fish impinged during June and July 1975-1977, and 1979 were adult alewives (Tables 2-6). During these months, alewives move inshore to spawn, and as in April, the increase in activity and density of fish apparently resulted in increased impingement of this species.

July 1978 was an exception to this pattern, as the species composition of impinged fish was very different (Table 5). Over 455,000 fish were impinged, the most fish impinged during any 1 mo of the 5-yr study period. However, only 34% of the fish impinged during July 1978 were alewives. From the large number of fish impinged, it is clear that the unusual species composition was not due to a scarcity of alewives, but rather the extraordinary abundance of several other species. Spottail shiners were nearly as abundant (33%) as alewives.

Other abundant species were trout-perch (17%), rainbow smelt (6%), bloater (5%), and yellow perch (5%). In July 1978, three upwellings occurred which were exceptional in their intensity (Appendix 9). On each occasion, water temperatures dropped 5-12°C and upwelling persisted 3 or 4 days. Upwelling increases fish activity and causes many fish to move shoreward seeking preferred warmer temperature (Wells 1968, Emery 1970, Jude et al. 1979). Rainbow smelt and bloater, which prefer cold water (Wells 1968, Jude et al. 1979), may accompany cold, upwelled water inshore.

Species composition of fish impinged during October was variable, but spottail shiner, trout-perch, and YOY (young-of-the-year) alewives, yellow perch, and smelt, were usually abundant. In 1976 there was no increase in number of fish impinged in October, nor was there as sharp a decrease in impingement rates during August and September as occurred in the other 2 yr of one unit operation (Tables 2-4). In 1976, August water temperatures were extraordinarily high (Appendix 7), and there was no upwelling during August to October. Instead, water temperatures declined gradually during September and October. The homogeneity and gradual change in water temperature may have led to a gradual change in species composition, with no abrupt shifts of fish abundance in the inshore area, or abrupt increase in fish activity.

As indicated by seine data (Appendixes 11-15), strong alewife year classes were produced in 1976 and 1979. This may indicate good survival and growth, as alewives attained a size (50 mm) at which they were retained by traveling screens as early as August in 1976 and 1979 (Appendixes 17, 20), whereas YOY were first impinged in September in other years (histograms for alewives, spottail shiners, trout-perch, yellow perch, and rainbow smelt impinged during 1975 through 1979 appear in Appendixes 16-40). Large YOY year classes contributed to

the relatively large number of fish impinged in August and September 1976 and in September 1979 (Appendixes 17, 20).

The biology of individual species is an important factor determining seasonal patterns in impingement rates. Alewives may be entrapped by plant intakes in large numbers just as inshore waters begin to warm in April. Alewife movement and density inshore may be determined by the differential rate of warming of inshore and offshore waters. Peak impingement of alewives during 1975-1979 usually occurred during June or July, when alewives moved inshore to spawn. In late summer or autumn there was an increase in impingement of YOY alewives, which by this time were large enough ($\geq$ 50 mm) to be retained by the traveling screens (Appendixes 16-20).

Spottail shiners prefer shallow depths and warm water (Jude et al. 1979, Wells 1968), and these preferences affected spottail shiner impingement rates. Impingement of spottail shiners increased in March and April as spottails moved shoreward seeking warmer, inshore water. In May and June, impingement of spottail shiners was low; field data indicated spottail shiners were mostly inshore of the intake depth (9 m). Peak spawning for spottail shiners occurs in July (Jude et al. 1979), and they also begin their post-spawning migration from the area this month. Large late summer impingement of spottail shiners in 1978 and 1979 was probably due to increased activity and offshore movement of spottail shiners during these months. Impingement of spottail shiners in October was usually due to offshore migration of adults and, in 1975-1977, of YOY (Appendixes 21-23), which by this time were large enough to be retained on the traveling screens. A few spottails remained inshore all winter. Winter impingement rates seemed dependent on water temperature, increasing when temperature in the area rose to 3°C or above, but there were exceptions.

Besides water temperature, winter impingement of spottail shiners was probably affected by attraction to the plume, winter storms, and ice cover.

Numbers of trout-perch impinged began to increase in April but did not become high until July. At this time, trout-perch move inshore for spawning, which continues throughout summer. Impingement of trout-perch during summer was spotty rather than continuous, and appeared to coincide with upwelling or storms. In 1978 and 1979, trout-perch impingement rates remained high through October; in 1975-1977, impingement losses tapered off during late summer and rose again in September or October as trout-perch migrated offshore. A few trout-perch were impinged during winter.

Impingement of yellow perch increased slightly in March and April, as inshore water temperatures warmed in the spring. Except for 1975, peak impingement of yellow perch occurred during July through September. Because this was past the spawning season for yellow perch, their mid-to-late summer abundance evidently reflected post-spawning migration into the Cook area after spawning in other areas of the lake (Jude et al. 1979, Dorr 1982). There is some evidence that impingement of yellow perch during summer increased sharply after storms. YOY yellow perch were first impinged in September and continued to be impinged during fall and winter, apparently remaining inshore, (Appendixes 31-35).

During 1975-1979, peak impingement of rainbow smelt occurred in spring, mostly during April and May. During these months, rainbow smelt migrate through the area as they move inshore to spawn (Jude et al. 1979). Because adult rainbow smelt prefer cold water (Jude et al. 1979, Wells 1968), they move offshore during months of warm water temperature. Impingement of rainbow smelt during the summer usually occurred when cold, upwelled water allowed smelt to move

shoreward. In 1978 and 1979 large numbers of rainbow smelt were impinged during summer. YOY smelt were impinged in September and October (Appendixes 36-40).

Impinged Fish Compared with Field-Caught Fish

In general, the most abundantly impinged species were also most abundant in field catches (Appendixes 1-5). Exceptions were bloater and sculpin, which were impinged in much higher numbers than would be predicted from field catches. Bloater field abundance increased dramatically during the last 2 yr of the study. Sculpins preferentially inhabited the riprap around the intake structure; preference for hiding in dark places and nocturnal activity patterns probably increased their susceptibility to entrapment.

Alewives and spottail shiners proportionally comprised a somewhat higher percentage in field catches than in impingement (70% and 20%, respectively, of all fish caught in standard series fishing 1975-1979). For alewives, the difference in proportion was primarily due to large numbers of seined YOY (Appendixes 41-45). Young-of-the-year alewives apparently were most abundant inshore of the intakes, and during most of the season they were too small (< 50 mm) to be impinged on the traveling screens (histograms for alewives, spottail shiners, trout-perch, and yellow perch caught in standard-series field sampling during 1975 through 1979 appear in Appendixes 41-65).

Trout-perch, yellow perch, and rainbow smelt each constituted 3% or less of the total field catch. These species often were most abundant in the area during upwelling, storms, or other conditions of weather and water temperature which not only increased fish density but also activity, and thus the chance that these fish would be entrapped (Lifton and Storr 1977).

Though in the most broad terms, over-all species composition of impinged fish was determined by local abundance of each species, there were exceptions,

and fluctuations in impingement rates seasonally or among years often showed little correlation with changes in field abundances of that species. As an example, yearly abundance of impinged and field-caught alewives (Fig. 1) were uncorrelated, and seasonal patterns of alewife impingement were not always predictable from seasonal alewife field abundance (Fig. 2). The lack of correlation portrayed for alewives was true of other species as well. The differences may be partially explained by limitations of field sampling, because each gear type only samples one 24-h period each month, but this explanation alone is inadequate. Young-of-the-year fish were often more abundant in field catches than they were in impingement samples, because they were most likely to be inshore of the intakes and because they were too small to be impinged.

Disproportionally high entrapment may occur when fish are attracted to the riprap or the intake structure; or when weather or water temperature changes increase horizontal or vertical movement of fish, or decrease fish avoidance of the intake structure or current. Sculpin spp. and yellow perch are examples of fish which are attracted to the riprap and apparently prefer that substrate over the flat sand bottom which characterizes field sampling stations. Sculpins, in particular, as confirmed by project divers (Dorr and Jude 1980), reside on the riprap almost exclusively. Divers also observed aggregations of yellow perch around the intakes (Dorr and Jude 1980), and yellow perch, sculpins, johnny darter, spottail shiners, and ninespine stickleback may use the riprap as a spawning substrate (Dorr 1982).

Trout-perch and rainbow smelt, however, are examples of fish which are not normally attracted to the intakes or riprap. Even when present inshore, they may not be impinged in large numbers unless weather or water temperature changes occur. Entrapment of all fish, even those which normally are attracted to the

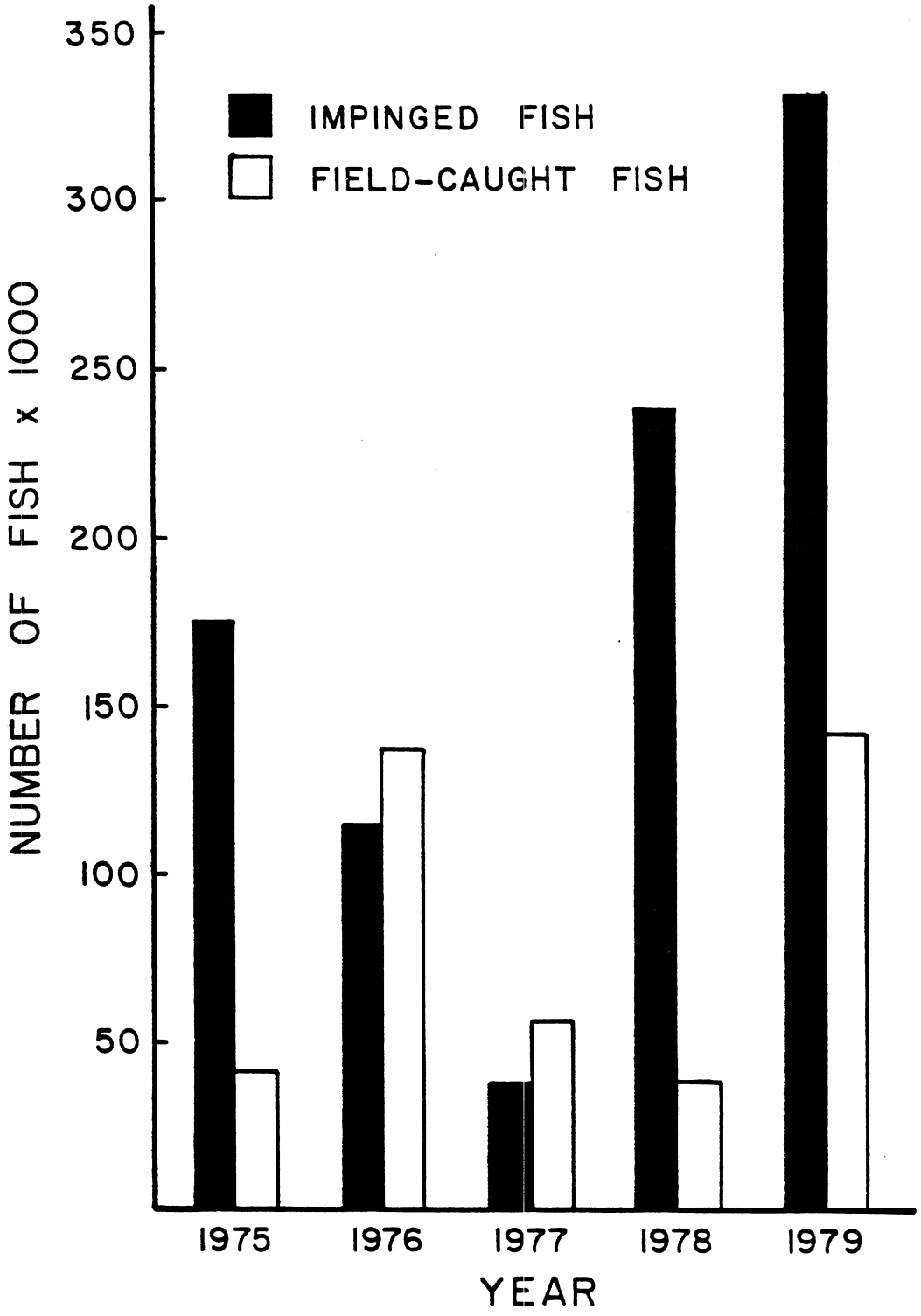

Figure 1. Number of alewives impinged and caught annually during field sampling at the Cook Plant, southeastern Lake Michigan, 1975-1979.

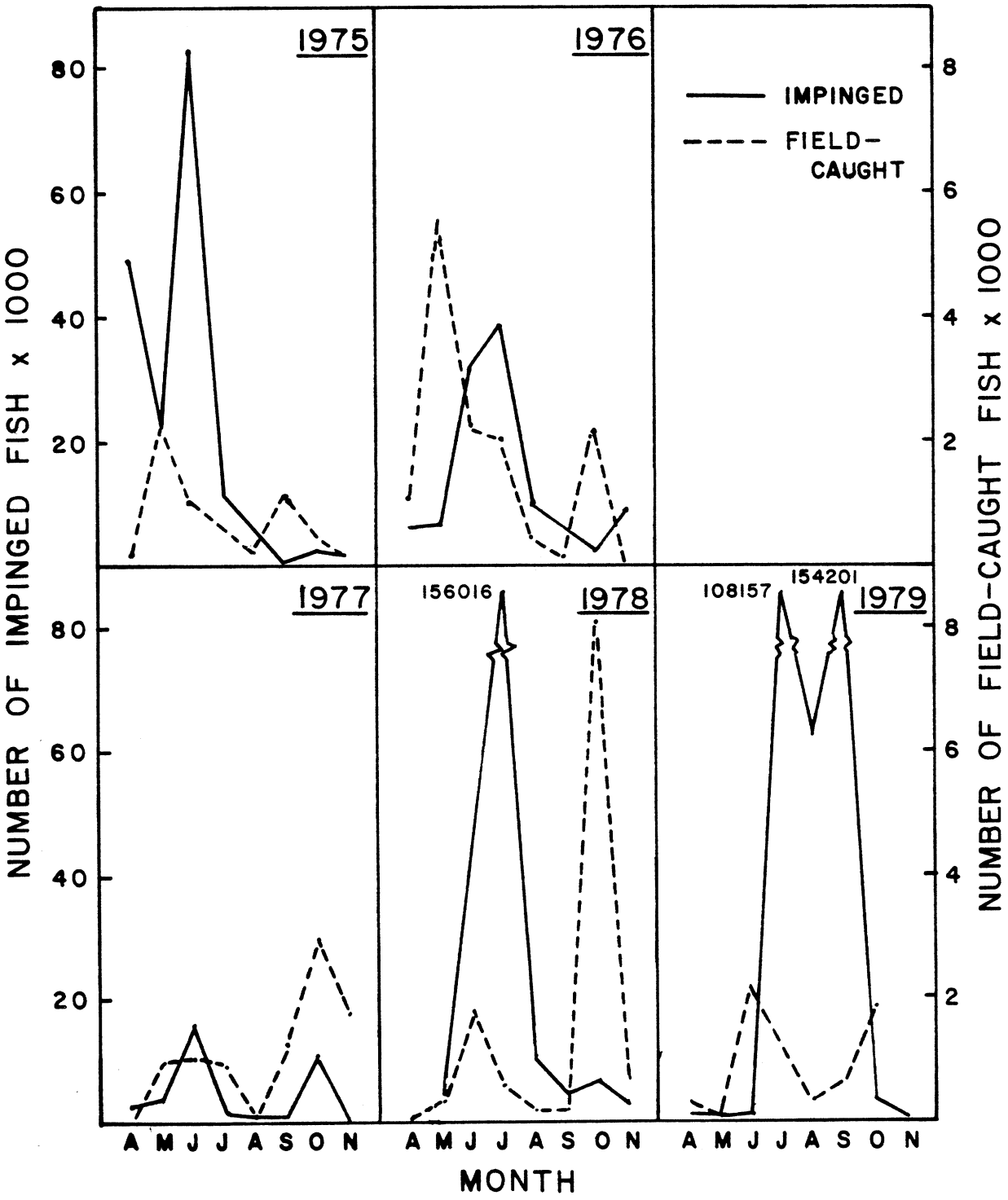

Figure 2. Seasonal abundance of impinged and field-caught alewives at the Cook Plant, southeastern Lake Michigan, 1975-1979.

intakes, increases when fish activity increases. Spawning, spring warming of inshore water, fall turn-over, upwelling, and storms are all conditions which increase fish movement through the area of the intakes. Upwelling can force fish to move upward in the water column (Emery 1970), increasing their chances of entrapment. Fish not only are more active during storms, but may shelter in the lee of an intake structure (Lifton and Storr 1977). Turbidity and turbulence associated with storms may also reduce fish awareness and avoidance of the intake structure and current.

Plant Effects

Two-unit operation increased cooling water flow rate from 2.7×10^6 liters/min to 6.1×10^6 liters/min (Table 7), and increased fish impingement during certain times of the year substantially over impingement during one-unit operation. In making comparisons of impingement rates, 1977 was not considered because so few fish were impinged compared with the preceding 2 years. Because 1977 was a year of one-unit operation, its exclusion should contribute to a more conservative estimate of the differences between one-unit and two-unit operation.

For the five most abundant species, percent increase in mean numbers impinged during two-unit operation (1978, 1979) compared with one-unit operation (1975, 1976) (Table 9) was far in excess of the 87% increase in cooling water volume (Table 7). Whether a relationship existed between increased impingement losses during the last 2 years of the study and changes in field abundance during these years is inconclusive. In general, there appeared to be little relationship. However, in the case of rainbow smelt, high field abundance may have contributed to impingement losses. Monthly impingement of each species (Tables 5, 6) indicated that extremely large numbers of fish were impinged

Table 9. Percent change in mean number of fish impinged and field-caught during two-unit operation (1978, 1979) over mean number impinged and field-caught during one-unit operation (1975, 1976).

Species	Percent change Impingement	Percent change Field Catch
Alewife	96	1
Spottail shiner	577	90
Trout-perch	303	69
Yellow perch	114	-9
Rainbow smelt	1226	232

during only a few months, (July, August, and September) which typically were months of high abundance of fish locally.

The plant was not operating at full two-unit capacity during much of April and May in either 1978 or 1979, thus data examined to date do not indicate the potential maximum impingement due to two-unit operation as fish move inshore during spring warming. Preliminary 1980 data, however, indicate that impingement of extremely large numbers of fish (> 1 million fish) is possible during this season. Zion Station in Illinois (Lake Michigan) experienced a similar influx of alewives during May 1975 (Kitchel 1975). Such heavy impingement losses may possibly affect local abundance of affected species, especially in combination with total impingement losses within the southern basin of Lake Michigan. Jensen et al. (1982) estimated that water withdrawal through all intakes on Lake Michigan reduced alewife biomass by nearly 3%, based on 1975 data. Many fish impinged at the Cook Plant during peak periods in 1978 and 1979 were YOY or yearlings which had not spawned (Appendixes 66, 68, 70, 72, 74) (composite yearly histograms for major species collected in standard-series field sampling during 1975 through 1979 appear in Appendixes 67, 69, 71, 73, 75). Losses among this age-group might be particularly detrimental. Because it appears that total impingement losses during 1980-1982 were quite high, analysis of impingement losses and field abundance during these years may be enlightening.

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Appendix 1. Number of fish caught by standard series trawling, gillnetting, and seining in Cook Plant study area, southeastern Lake Michigan, 1975. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	ND	797	176	6974	2718	1096	757	7740	21188	168	42	41656	58.74
Spottail shiner	1	ND	12	103	1740	8483	3076	1583	2022	1535	428	831	19814	27.94
Yellow perch	7	ND	29	12	4	968	2143	560	280	151	103	80	4337	6.12
Rainbow smelt	3	ND	21	255	1233	1032	0	173	94	179	105	14	3109	4.38
Trout-perch	0	ND	0	14	151	221	68	114	150	108	51	28	905	1.28
Gizzard shad	0	ND	0	2	0	0	0	28	18	13	106	26	193	0.27
Johnny darter	0	ND	0	2	35	19	3	5	31	19	19	9	142	0.20
Slimy sculpin	0	ND	0	38	48	12	0	1	1	2	5	4	111	0.16
Longnose sucker	1	ND	50	3	9	22	1	2	1	2	3	0	94	0.13
White sucker	1	ND	7	3	6	37	9	0	17	2	2	5	89	0.13
Lake trout	0	ND	1	3	8	21	0	0	0	4	47	1	85	0.12
Coho salmon	0	ND	6	40	1	12	0	2	0	0	2	0	63	0.09
Chinook salmon	0	ND	0	3	0	11	3	3	2	20	7	1	50	0.07
Common carp	0	ND	0	0	1	0	14	14	17	2	2	0	50	0.07
Bloater	0	ND	0	0	2	34	0	11	1	1	0	0	49	0.07
Sand shiner	0	ND	0	0	0	0	0	0	1	1	32	0	34	0.05
Brown trout	0	ND	7	2	1	1	1	1	1	1	10	1	26	0.04
Ninespine stickleback	0	ND	0	2	10	14	0	0	0	0	0	0	26	0.04
Longnose dace	0	ND	0	0	0	1	0	2	2	7	6	0	18	0.03
Burbot	1	ND	0	0	0	0	0	0	0	1	0	13	15	0.02
Rainbow trout	0	ND	1	2	0	0	1	0	1	6	3	1	15	0.02
Channel catfish	0	ND	0	0	0	0	1	1	5	1	1	0	9	0.01
Northern pike	1	ND	0	1	0	1	0	0	0	0	3	0	6	0.01
Shorthead redhorse	0	ND	0	0	0	0	0	0	4	0	0	0	4	0.01
Lake whitefish	0	ND	0	1	0	1	0	0	0	0	0	0	2	<0.01
Logperch	0	ND	0	0	1	1	0	0	0	0	0	0	2	<0.01
Bluegill	0	ND	0	0	0	1	0	0	1	0	0	0	2	<0.01
Silver redhorse	0	ND	0	0	0	0	0	0	0	1	0	0	1	<0.01
Emerald shiner	0	ND	0	1	0	0	0	0	0	0	0	0	1	<0.01
Lake herring	0	ND	0	1	0	0	0	0	0	0	0	0	1	<0.01
Pumpkinseed	0	ND	0	0	0	0	1	0	0	0	0	0	1	<0.01
Quillback	0	ND	0	0	0	1	0	0	0	0	0	0	1	<0.01
Largemouth bass	0	ND	0	0	0	1	0	0	0	0	0	0	1	<0.01
Lake sturgeon	0	ND	0	0	1	0	0	0	0	0	0	0	1	<0.01
Totals	15	ND	931	664	10225	13612	6417	3257	10389	23244	1103	1056	70913	

Appendix 2. Number of fish caught by standard series trawling, gillnetting, and seining in Cook Plant study area, southeastern Lake Michigan, 1976. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	0	204	2020	7446	3862	2852	43406	74708	2225	20	ND	136743	86.77
Spottail shiner	ND	47	49	967	1708	3307	5309	580	823	1178	147	ND	14115	8.96
Yellow perch	ND	13	5	54	24	318	1242	386	422	30	4	ND	2498	1.59
Trout-perch	ND	2	1	25	118	115	1146	134	261	145	8	ND	1955	1.24
Rainbow smelt	ND	1	21	452	67	143	416	19	11	13	122	ND	1265	0.80
Johnny darter	ND	0	0	2	139	12	25	30	31	59	6	ND	304	0.19
Bloater	ND	0	0	3	2	26	76	0	0	0	0	ND	107	0.07
Brown trout	ND	6	0	2	32	18	10	1	17	4	0	ND	90	0.06
White sucker	ND	4	0	6	24	5	18	5	18	8	1	ND	89	0.06
Slimy sculpin	ND	0	0	55	12	1	0	6	2	5	3	ND	84	0.05
Gizzard shad	ND	1	0	0	0	1	1	20	20	7	1	ND	51	0.03
Coho salmon	ND	0	0	0	27	16	1	0	1	1	0	ND	46	0.03
Longnose sucker	ND	20	3	8	4	3	2	0	0	0	0	ND	40	0.03
Sand shiner	ND	0	0	1	0	0	0	7	0	31	0	ND	39	0.03
Lake trout	ND	0	3	6	8	7	2	0	0	11	0	ND	37	0.02
Common carp	ND	0	0	0	10	2	1	14	4	1	0	ND	32	0.02
Longnose dace	ND	0	0	1	3	2	1	5	10	1	4	ND	27	0.02
Chinook salmon	ND	1	0	0	0	9	1	0	3	0	0	ND	14	0.01
Rainbow trout	ND	2	0	2	2	1	1	0	4	2	0	ND	14	0.01
Channel catfish	ND	0	0	0	2	0	1	2	8	0	0	ND	13	0.01
Ninespine stickleback	ND	0	0	0	8	1	0	0	0	0	0	ND	9	0.01
Burbot	ND	1	0	2	0	0	1	0	0	2	0	ND	6	<0.01
Lake whitefish	ND	0	1	2	1	1	1	0	0	0	0	ND	6	<0.01
Silver redhorse	ND	0	0	0	0	0	3	0	0	0	0	ND	3	<0.01
Bluegill	ND	0	0	0	1	0	1	0	0	0	1	ND	3	<0.01
Quillback	ND	0	0	0	0	1	1	0	0	0	0	ND	2	<0.01
Golden shiner	ND	1	0	0	0	0	0	0	0	1	0	ND	2	<0.01
Brook silverside	ND	0	0	1	0	0	0	0	0	0	0	ND	1	<0.01
Smallmouth bass	ND	0	0	0	0	0	0	1	0	0	0	ND	1	<0.01
Largemouth bass	ND	0	0	0	0	0	0	1	0	0	0	ND	1	<0.01
Lake sturgeon	ND	0	0	0	1	0	0	0	0	0	0	ND	1	<0.01
Totals	ND	99	287	3609	9639	7851	11112	44617	76343	3724	317	ND	157598	

Appendix 3. Number of fish caught by standard series trawling, gillnetting, and seining in Cook Plant study area, southeastern Lake Michigan, 1977. ND = no data.

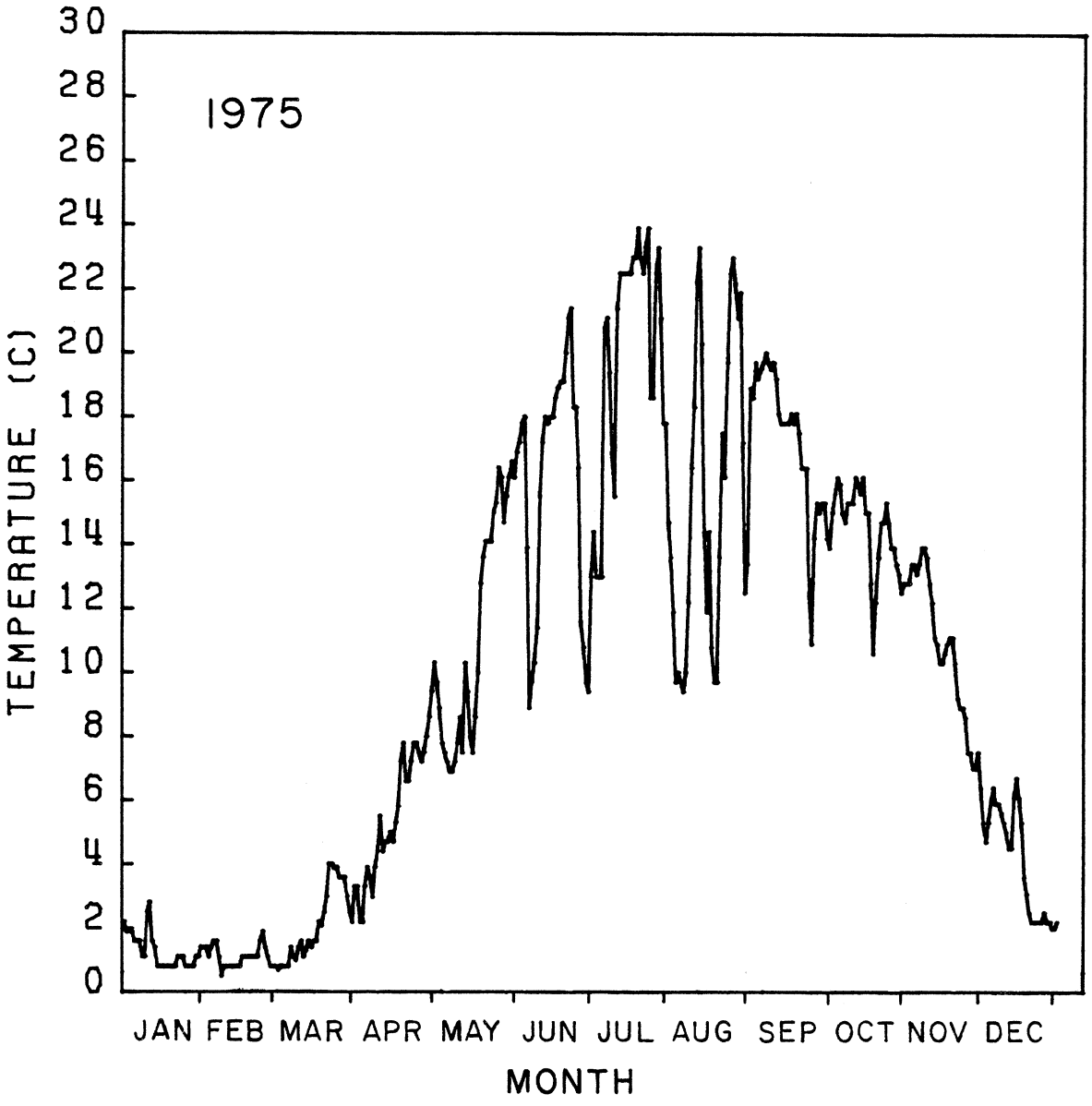
Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	66	34	1270	1607	3507	20151	12731	3017	13596	0	55979	63.36
Spottail shiner	ND	ND	54	20	2333	2190	2363	10098	3535	1564	398	0	22555	25.54
Yellow perch	ND	ND	11	28	19	189	1300	897	470	47	416	1	3378	3.82
Trout-perch	ND	ND	1	4	193	317	1919	130	172	501	2	0	3239	3.67
Rainbow smelt	ND	ND	0	113	170	2	669	88	99	148	166	0	1455	1.65
Johnny darter	ND	ND	0	34	171	44	31	41	82	4	16	0	423	0.48
Bloater	ND	ND	0	0	0	24	40	0	7	141	15	0	227	0.26
Lake trout	ND	ND	4	10	6	6	6	0	9	27	119	0	187	0.21
White sucker	ND	ND	0	8	29	18	68	13	23	8	5	1	173	0.20
Gizzard shad	ND	ND	0	0	0	0	1	15	39	41	8	0	104	0.12
Longnose sucker	ND	ND	4	5	3	0	34	9	14	6	24	0	99	0.11
Coho salmon	ND	ND	3	1	83	2	0	0	1	2	4	0	96	0.11
Common carp	ND	ND	0	5	30	0	5	22	20	3	7	0	92	0.10
Chinook salmon	ND	ND	11	21	0	43	0	0	0	1	0	0	76	0.09
Brown trout	ND	ND	5	9	8	13	5	0	5	1	9	6	61	0.07
Longnose dace	ND	ND	0	1	0	3	1	0	9	38	8	0	60	0.07
Slimy sculpin	ND	ND	0	15	0	0	7	1	2	0	5	0	30	0.03
Emerald shiner	ND	ND	0	0	0	2	23	0	0	3	0	0	28	0.03
Sand shiner	ND	ND	0	1	0	2	13	5	1	0	1	0	23	0.03
Rainbow trout	ND	ND	0	2	1	0	1	0	6	0	2	0	12	0.01
Golden redhorse	ND	ND	0	0	0	0	0	6	3	0	0	0	9	0.01
Channel catfish	ND	ND	0	0	0	0	0	5	2	2	0	0	9	0.01
Burbot	ND	ND	1	0	0	0	0	1	0	0	0	6	8	0.01
Ninespine stickleback	ND	ND	0	0	5	0	2	0	0	0	0	0	7	0.01
Quillback	ND	ND	0	0	0	0	0	1	2	0	0	0	3	<0.01
Mottled sculpin	ND	ND	0	0	0	0	0	0	0	3	0	0	3	<0.01
Bluegill	ND	ND	0	0	0	1	0	0	1	0	0	0	2	<0.01
Lake sturgeon	ND	ND	0	0	0	0	1	1	0	0	0	0	2	<0.01
Bluntnose minnow	ND	ND	0	0	0	0	0	1	0	0	0	0	1	<0.01
Golden shiner	ND	ND	0	0	0	0	0	0	1	0	0	0	1	<0.01
Rock bass	ND	ND	0	0	0	0	0	0	0	1	0	0	1	<0.01
Silver redhorse	ND	ND	0	0	0	0	0	0	1	0	0	0	1	<0.01
Shorthead redhorse	ND	ND	0	0	0	0	0	0	0	0	0	1	1	<0.01
Freshwater drum	ND	ND	0	0	0	0	0	0	0	1	0	0	1	<0.01
Totals	ND	ND	160	311	4321	4463	9996	31485	17235	5559	14801	15	88346	

Appendix 4. Number of fish caught by standard series trawling, gillnetting, and seining in Cook Plant study area, southeastern Lake Michigan, 1978. ND = no data.

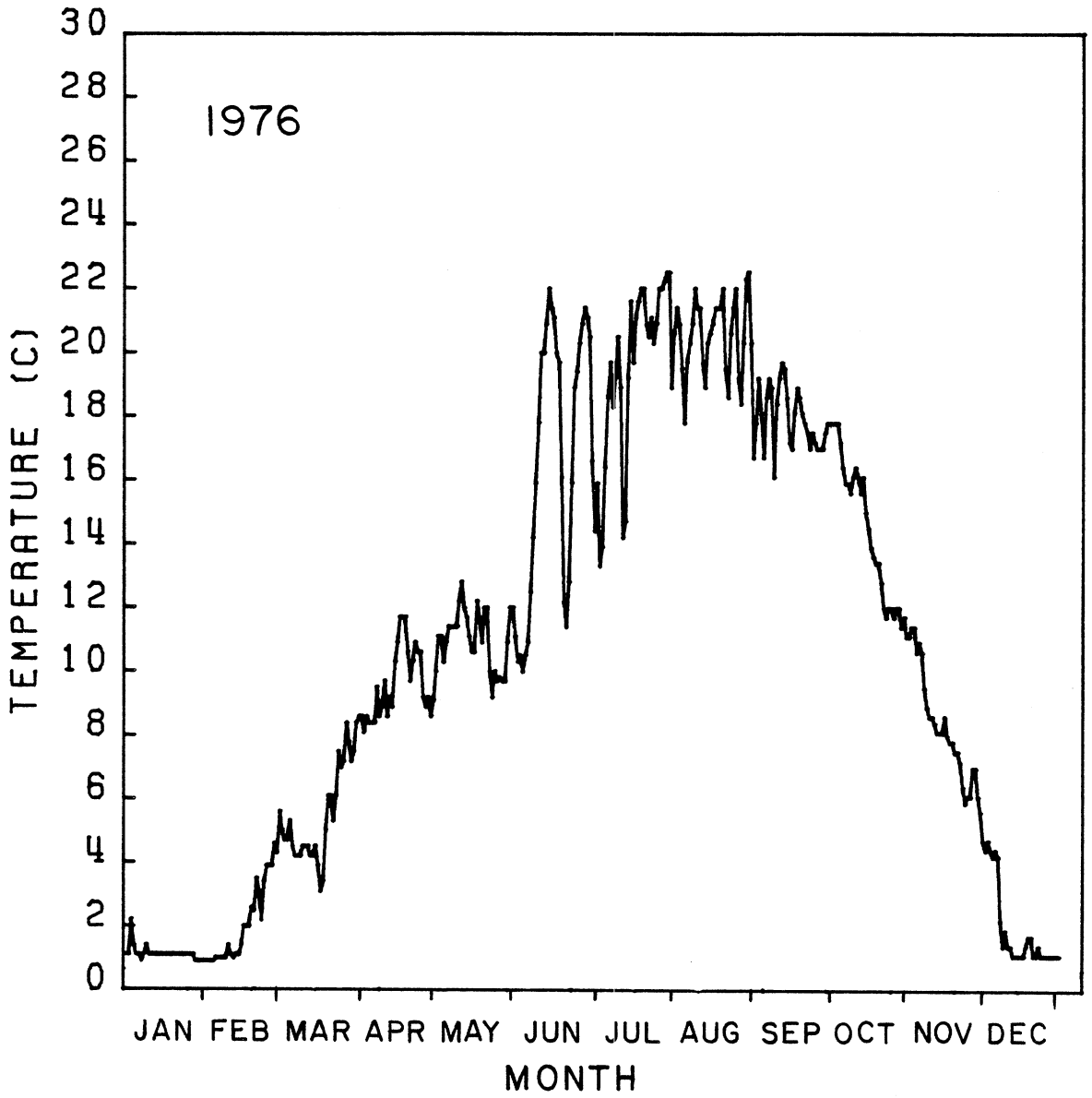
Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	4	294	5498	641	1786	2686	26882	701	ND	38492	41.79
Spottail shiner	ND	ND	ND	108	414	6824	15913	6064	2288	4788	202	ND	36601	39.73
Rainbow smelt	ND	ND	ND	66	1580	59	1844	5446	89	109	68	ND	9261	10.05
Trout-perch	ND	ND	ND	5	80	194	610	310	254	1631	20	ND	3104	3.37
Yellow perch	ND	ND	ND	50	4	181	379	206	609	57	90	ND	1576	1.71
Bloater	ND	ND	ND	0	1	117	269	868	29	52	56	ND	1392	1.51
Johnny darter	ND	ND	ND	1	77	57	82	17	5	112	34	ND	385	0.42
Coho salmon	ND	ND	ND	11	23	224	22	17	4	0	0	ND	301	0.33
Lake trout	ND	ND	ND	9	34	31	18	11	89	53	41	ND	286	0.31
Brown trout	ND	ND	ND	63	12	9	10	11	30	17	10	ND	162	0.18
White sucker	ND	ND	ND	1	6	9	15	9	36	31	11	ND	118	0.13
Gizzard shad	ND	ND	ND	0	0	0	0	0	12	88	8	ND	108	0.12
Chinook salmon	ND	ND	ND	7	6	55	4	2	7	22	4	ND	107	0.12
Longnose sucker	ND	ND	ND	14	2	2	1	7	12	8	25	ND	71	0.08
Common carp	ND	ND	ND	0	4	0	1	2	6	16	5	ND	34	0.04
Longnose dace	ND	ND	ND	3	3	2	0	0	5	8	5	ND	26	0.03
Rainbow trout	ND	ND	ND	4	1	2	2	5	1	5	1	ND	21	0.02
Slimy sculpin	ND	ND	ND	5	6	1	1	0	0	1	0	ND	14	0.02
Sand shiner	ND	ND	ND	0	0	0	0	0	12	0	0	ND	12	0.01
Emerald shiner	ND	ND	ND	0	0	0	0	3	0	7	0	ND	10	0.01
Lake whitefish	ND	ND	ND	0	1	3	0	2	2	0	1	ND	9	0.01
Channel catfish	ND	ND	ND	0	0	0	1	0	1	2	1	ND	5	0.01
Burbot	ND	ND	ND	2	1	0	0	0	0	1	1	ND	5	0.01
Ninespine stickleback	ND	ND	ND	1	2	1	0	0	1	0	0	ND	5	0.01
Spotfin shiner	ND	ND	ND	0	0	0	0	0	2	0	0	ND	2	<0.01
Northern pike	ND	ND	ND	0	0	0	0	0	0	2	0	ND	2	<0.01
Quillback	ND	ND	ND	0	0	0	0	0	0	2	0	ND	2	<0.01
Golden shiner	ND	ND	ND	0	0	0	2	0	0	0	0	ND	2	<0.01
Silver redhorse	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Brook silverside	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Lake herring	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Lake sturgeon	ND	ND	ND	0	0	0	0	0	0	0	1	ND	1	<0.01
Fathead minnow	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Totals	ND	ND	ND	355	2551	13269	19815	14766	6182	34895	1285	ND	92118	

Appendix 5. Number of fish caught by standard series trawling, gillnetting, and seining in Cook Plant study area, southeastern Lake Michigan, 1979. ND = no data.

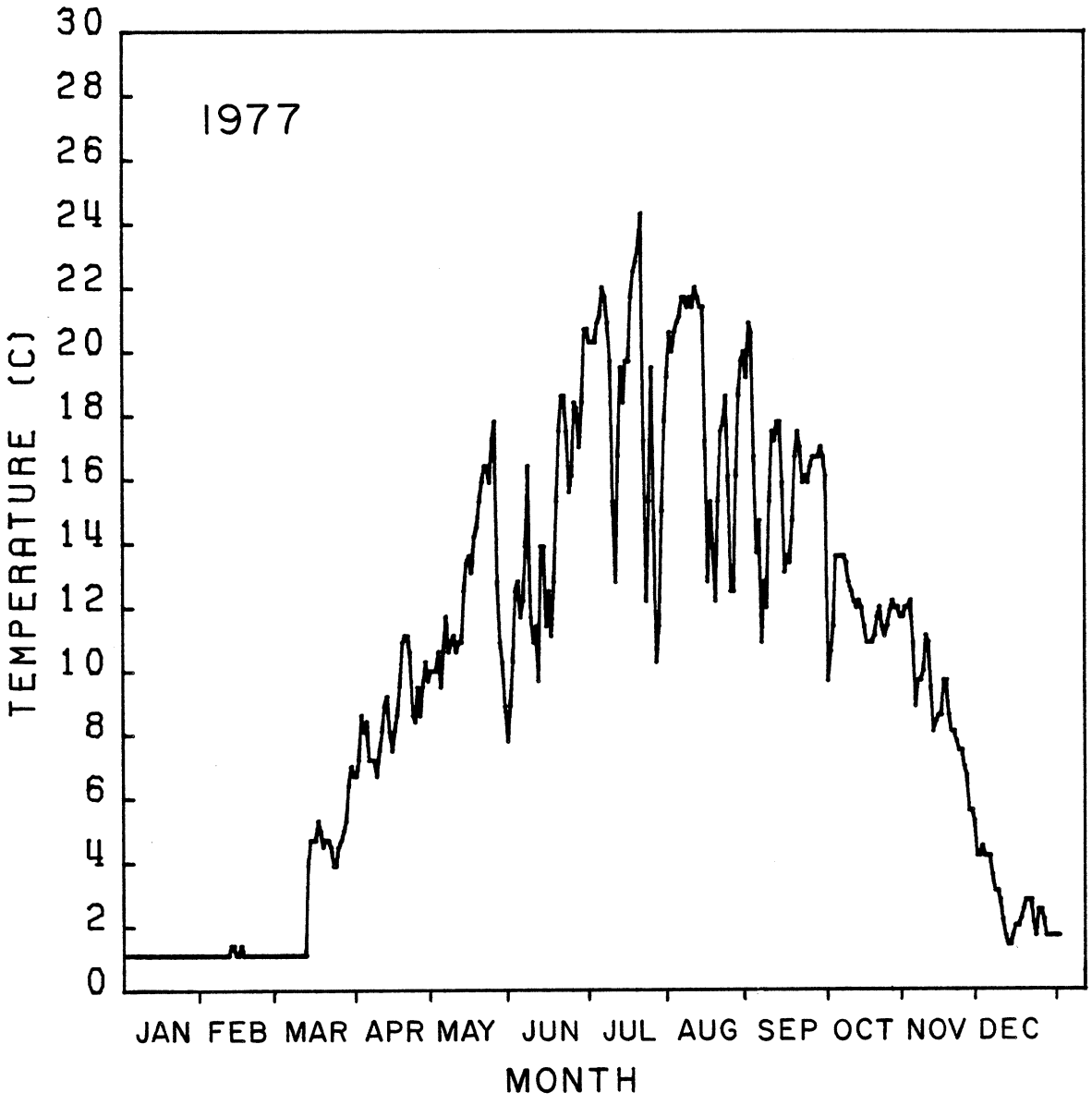
Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	267	71	2248	1178	16700	66560	54607	140	ND	141771	76.28
Spottail shiner	ND	ND	ND	711	834	3475	9796	2147	8582	2080	200	ND	27825	14.97
Rainbow smelt	ND	ND	ND	788	2152	579	146	923	54	150	467	ND	5259	2.83
Yellow perch	ND	ND	ND	41	25	104	511	1031	2733	63	151	ND	4659	2.51
Bloater	ND	ND	ND	0	4	68	1979	3	518	90	347	ND	3009	1.62
Trout-perch	ND	ND	ND	41	27	152	326	376	324	461	23	ND	1730	0.93
Chinook salmon	ND	ND	ND	168	83	61	1	1	7	0	1	ND	322	0.17
Johnny darter	ND	ND	ND	20	52	53	38	1	42	20	7	ND	233	0.13
White sucker	ND	ND	ND	40	19	31	8	41	30	18	1	ND	188	0.10
Lake trout	ND	ND	ND	15	3	4	0	2	0	55	85	ND	164	0.09
Gizzard shad	ND	ND	ND	3	0	1	0	6	124	17	8	ND	159	0.09
Slimy sculpin	ND	ND	ND	89	28	7	1	0	0	1	2	ND	128	0.07
Longnose sucker	ND	ND	ND	2	35	20	5	9	20	7	0	ND	98	0.05
Common carp	ND	ND	ND	11	29	7	2	12	3	7	0	ND	71	0.04
Coho salmon	ND	ND	ND	39	26	0	0	0	0	0	0	ND	65	0.03
Brown trout	ND	ND	ND	20	10	9	11	0	1	4	5	ND	60	0.03
Rainbow trout	ND	ND	ND	3	1	1	1	1	2	2	3	ND	14	0.01
Emerald shiner	ND	ND	ND	7	1	3	0	0	0	0	1	ND	12	0.01
Silver redhorse	ND	ND	ND	0	0	0	0	1	6	3	0	ND	10	0.01
Channel catfish	ND	ND	ND	1	0	0	0	3	3	1	0	ND	8	<0.01
Ninespine stickleback	ND	ND	ND	0	1	7	0	0	0	0	0	ND	8	<0.01
Sand shiner	ND	ND	ND	0	0	0	0	0	0	7	0	ND	7	<0.01
Lake whitefish	ND	ND	ND	3	3	1	0	0	0	0	0	ND	7	<0.01
Longnose dace	ND	ND	ND	3	0	0	0	0	1	2	0	ND	6	<0.01
Mottled sculpin	ND	ND	ND	2	0	0	0	0	0	0	4	ND	6	<0.01
Burbot	ND	ND	ND	1	0	2	0	2	0	0	0	ND	5	<0.01
Shorthead redhorse	ND	ND	ND	1	0	0	1	0	0	2	0	ND	4	<0.01
Northern pike	ND	ND	ND	0	0	0	0	1	3	0	0	ND	4	<0.01
Spotfin shiner	ND	ND	ND	0	0	0	0	2	0	1	0	ND	3	<0.01
Golden redhorse	ND	ND	ND	0	0	0	0	0	3	0	0	ND	3	<0.01
Round whitefish	ND	ND	ND	1	0	0	0	0	0	1	0	ND	2	<0.01
Fathead minnow	ND	ND	ND	0	0	1	0	1	0	0	0	ND	2	<0.01
Central mudminnow	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Bluntnose minnow	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Lake chub	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Black crappie	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Green sunfish	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Bluegill	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	2279	3406	6836	14004	21263	79016	57599	1445	ND	185848	



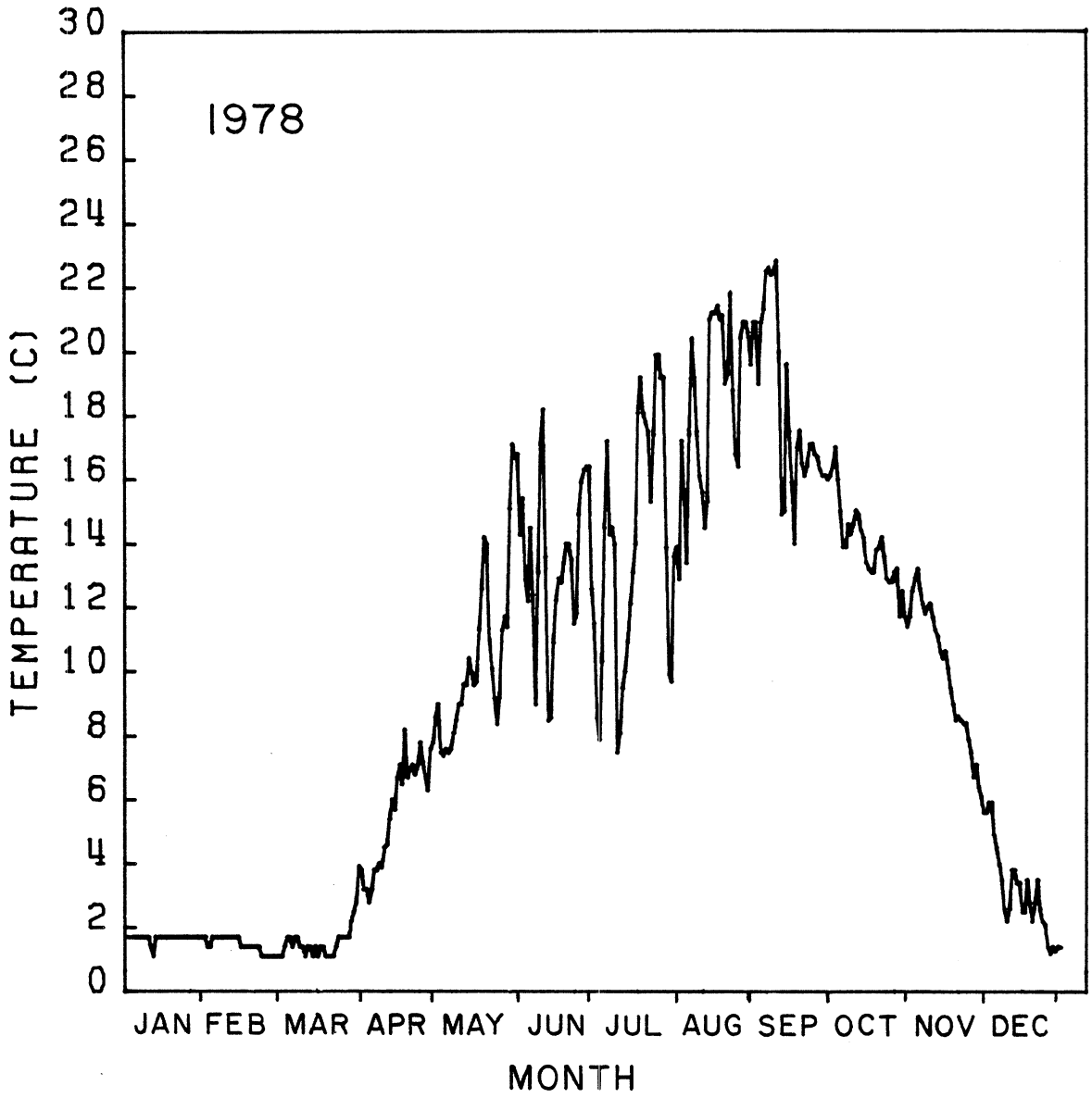
Appendix 6. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1975. Intake depth was 6 m.



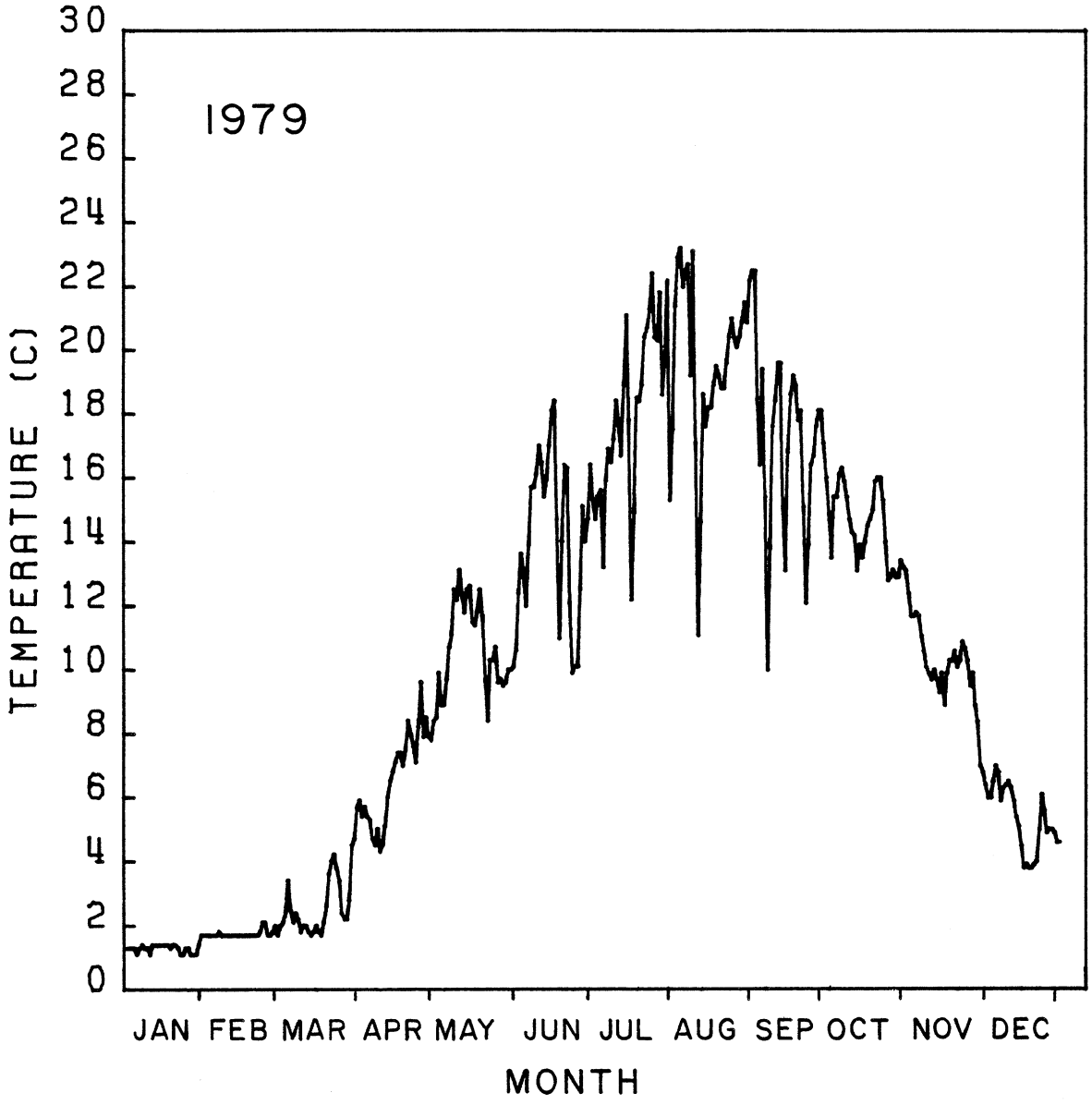
Appendix 7. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1976. Intake depth was 6 m.



Appendix 8. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1977. Intake depth was 6 m.



Appendix 9. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1978. Intake depth was 6 m.



Appendix 10. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1979. Intake depth was 6 m.

Appendix 11. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1975. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	0	4775	1708	424	540	5569	20740	18	ND	33774	65.96
Spottail shiner	ND	ND	ND	52	976	7596	2679	927	1118	1311	251	ND	14911	29.09
Yellow perch	ND	ND	ND	0	0	722	1209	62	1	0	12	ND	2006	3.91
Rainbow smelt	ND	ND	ND	84	127	0	0	0	2	1	0	ND	214	0.42
Gizzard shad	ND	ND	ND	2	0	0	0	0	2	12	104	ND	120	0.23
Trout-perch	ND	ND	ND	1	5	0	0	4	41	15	0	ND	66	0.13
Sand shiner	ND	ND	ND	0	0	0	0	0	1	1	32	ND	34	0.07
Longnose dace	ND	ND	ND	0	0	1	0	2	2	7	6	ND	18	0.04
Slimy sculpin	ND	ND	ND	1	17	0	0	0	0	0	0	ND	18	0.04
Chinook salmon	ND	ND	ND	3	0	11	2	0	0	1	0	ND	17	0.03
Johnny darter	ND	ND	ND	0	0	3	0	2	0	0	9	ND	14	0.03
Rainbow trout	ND	ND	ND	2	0	0	1	0	0	6	3	ND	12	0.02
Brown trout	ND	ND	ND	0	1	0	1	0	0	0	10	ND	12	0.02
Coho salmon	ND	ND	ND	0	0	7	0	0	0	0	1	ND	8	0.02
Ninespine stickleback	ND	ND	ND	2	5	0	0	0	0	0	0	ND	7	0.01
White sucker	ND	ND	ND	2	2	0	1	0	0	0	0	ND	5	0.01
Northern pike	ND	ND	ND	1	0	0	0	0	0	0	3	ND	4	0.01
Common carp	ND	ND	ND	0	1	0	3	0	0	0	0	ND	4	0.01
Bluegill	ND	ND	ND	0	0	1	0	0	1	0	0	ND	2	<0.01
Emerald shiner	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Channel catfish	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Largemouth bass	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Bloater	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Quillback	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Pumpkinseed	ND	ND	ND	0	0	0	1	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	151	5909	10051	4321	1538	6739	22094	449	ND	51252	

Appendix 12. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1976. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	0	ND	5	1905	1654	824	42919	74554	49	0	ND	121910	91.82
Spottail shiner	ND	7	ND	122	873	2881	4857	343	250	3	1	ND	9337	7.03
Yellow perch	ND	0	ND	0	0	16	750	16	13	0	0	ND	795	0.60
Rainbow smelt	ND	0	ND	300	13	0	0	5	7	0	1	ND	326	0.25
Trout-perch	ND	2	ND	9	9	1	32	38	25	0	1	ND	117	0.09
Brown trout	ND	4	ND	1	31	17	8	0	16	3	0	ND	80	0.06
Sand shiner	ND	0	ND	1	0	0	0	7	0	31	0	ND	39	0.03
Longnose dace	ND	0	ND	1	3	2	1	5	10	1	4	ND	27	0.02
White sucker	ND	1	ND	1	13	2	3	0	0	1	1	ND	22	0.02
Slimy sculpin	ND	0	ND	17	0	1	0	2	1	0	0	ND	21	0.02
Coho salmon	ND	0	ND	0	8	10	1	0	1	1	0	ND	21	0.02
Rainbow trout	ND	1	ND	2	2	1	1	0	4	2	0	ND	13	0.01
Common carp	ND	0	ND	0	10	2	0	0	0	0	0	ND	12	0.01
Lake trout	ND	0	ND	1	0	0	0	0	0	9	0	ND	10	0.01
Chinook salmon	ND	1	ND	0	0	9	0	0	0	0	0	ND	10	0.01
Johnny darter	ND	0	ND	0	0	3	0	4	1	0	0	ND	8	0.01
Gizzard shad	ND	1	ND	0	0	1	0	0	2	1	0	ND	5	<0.01
Silver redhorse	ND	0	ND	0	0	0	3	0	0	0	0	ND	3	<0.01
Bloater	ND	0	ND	0	1	0	2	0	0	0	0	ND	3	<0.01
Golden shiner	ND	1	ND	0	0	0	0	0	0	1	0	ND	2	<0.01
Channel catfish	ND	0	ND	0	1	0	1	0	0	0	0	ND	2	<0.01
Bluegill	ND	0	ND	0	0	0	1	0	0	0	1	ND	2	<0.01
Ninespine stickleback	ND	0	ND	0	1	1	0	0	0	0	0	ND	2	<0.01
Quillback	ND	0	ND	0	0	1	1	0	0	0	0	ND	2	<0.01
Longnose sucker	ND	0	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Brook silverside	ND	0	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Smallmouth bass	ND	0	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Largemouth bass	ND	0	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Totals	ND	18	ND	462	2870	4602	6485	43341	74884	102	9	ND	132773	

Appendix 13. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1977. ND = no data.

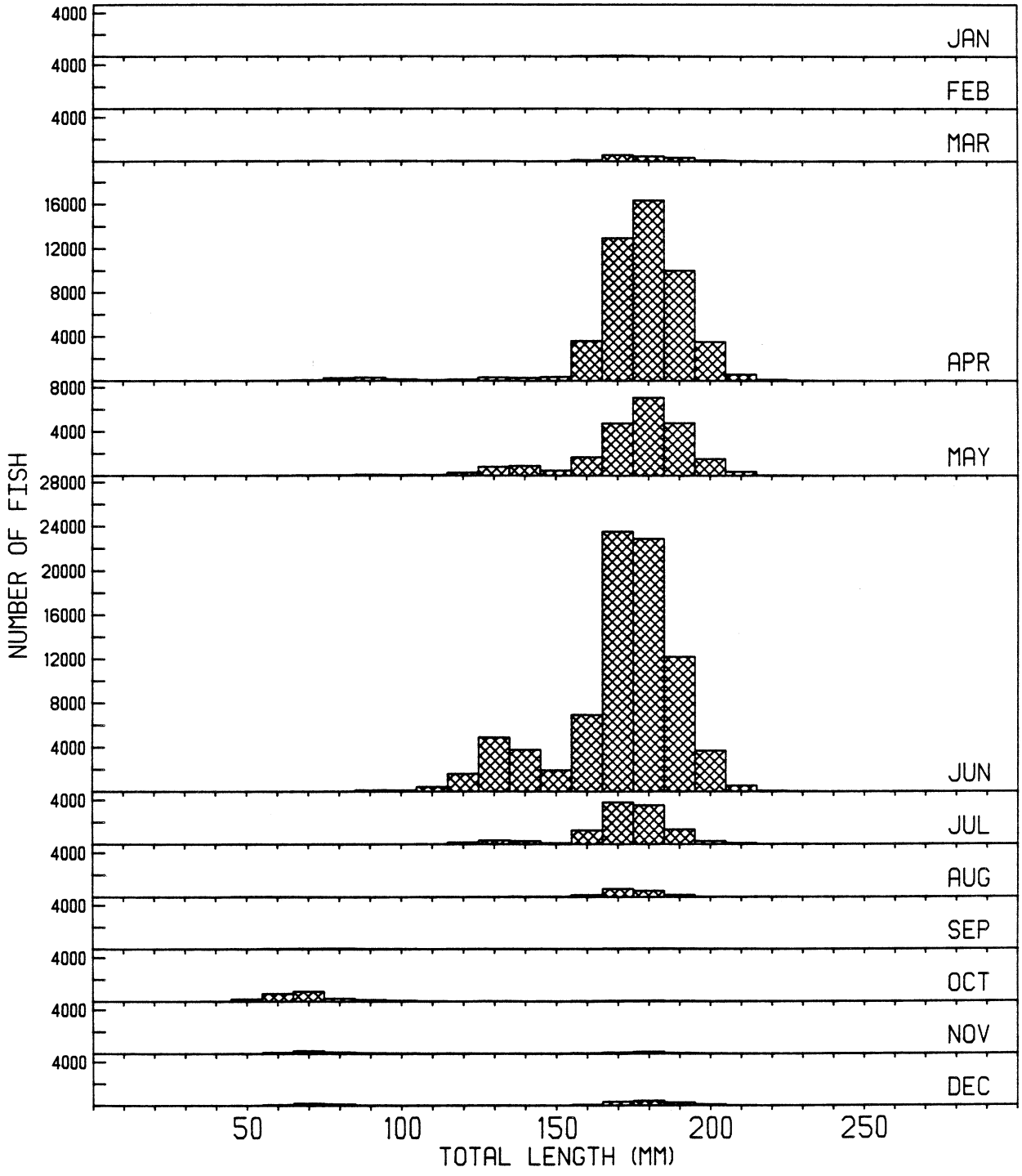
Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	6	298	573	2590	20022	11451	51	11812	ND	46803	74.57
Spottail shiner	ND	ND	ND	11	1310	960	2235	8453	239	274	356	ND	13838	22.05
Yellow perch	ND	ND	ND	0	1	1	1004	25	3	0	285	ND	1319	2.10
Trout-perch	ND	ND	ND	0	7	99	4	9	91	3	1	ND	214	0.34
Rainbow smelt	ND	ND	ND	3	2	1	0	0	15	20	62	ND	103	0.16
Coho salmon	ND	ND	ND	1	83	2	0	0	0	0	3	ND	89	0.14
Longnose dace	ND	ND	ND	1	0	3	1	0	9	37	8	ND	59	0.09
White sucker	ND	ND	ND	3	5	14	16	0	2	2	2	ND	44	0.07
Chinook salmon	ND	ND	ND	0	0	42	0	0	0	0	0	ND	42	0.07
Common carp	ND	ND	ND	3	27	0	4	4	0	1	2	ND	41	0.07
Brown trout	ND	ND	ND	9	3	8	3	0	1	0	6	ND	30	0.05
Emerald shiner	ND	ND	ND	0	0	2	23	0	0	3	0	ND	28	0.04
Sand shiner	ND	ND	ND	1	0	2	13	5	1	0	1	ND	23	0.04
Rainbow trout	ND	ND	ND	2	1	0	0	0	6	0	0	ND	9	0.01
Bloater	ND	ND	ND	0	0	1	0	0	5	0	3	ND	9	0.01
Slimy sculpin	ND	ND	ND	1	0	0	0	0	0	0	3	ND	4	0.01
Quillback	ND	ND	ND	0	0	0	0	1	1	0	0	ND	2	<0.01
Bluegill	ND	ND	ND	0	0	1	0	0	1	0	0	ND	2	<0.01
Lake trout	ND	ND	ND	0	0	0	0	0	0	0	1	ND	1	<0.01
Rock bass	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Longnose sucker	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Channel catfish	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Bluntnose minnow	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Golden shiner	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Freshwater drum	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Totals	ND	ND	ND	41	1737	1709	5893	28522	11826	393	12545	ND	62666	

Appendix 14. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1978. ND = no data.

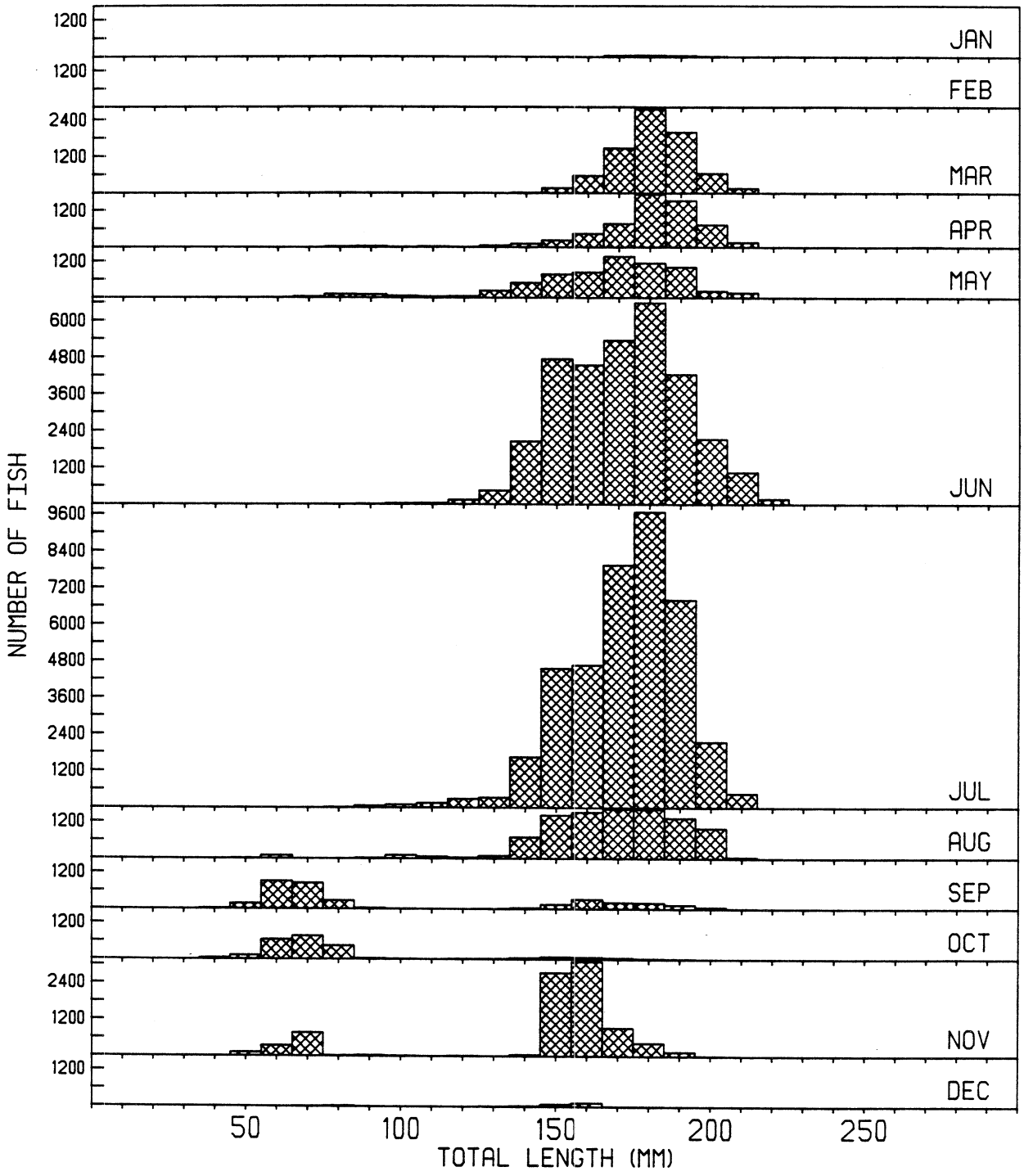
Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	33	24	5438	15905	5830	1246	2	12	ND	28490	50.49
Alewife	ND	ND	ND	0	0	3717	90	1630	2553	18839	6	ND	26835	47.56
Rainbow smelt	ND	ND	ND	0	81	12	283	0	0	2	1	ND	379	0.67
Yellow perch	ND	ND	ND	1	0	0	263	7	20	0	1	ND	292	0.52
Coho salmon	ND	ND	ND	2	15	220	11	0	0	0	0	ND	248	0.44
Brown trout	ND	ND	ND	58	7	9	7	0	0	1	0	ND	82	0.14
Trout-perch	ND	ND	ND	1	3	39	32	0	5	0	0	ND	80	0.14
Chinook salmon	ND	ND	ND	0	0	55	0	0	0	0	0	ND	55	0.10
Longnose dace	ND	ND	ND	3	3	2	0	0	5	8	5	ND	26	0.05
White sucker	ND	ND	ND	1	2	1	14	1	0	0	2	ND	21	0.04
Rainbow trout	ND	ND	ND	3	1	2	2	4	1	4	1	ND	18	0.03
Sand shiner	ND	ND	ND	0	0	0	0	0	12	0	0	ND	12	0.02
Emerald shiner	ND	ND	ND	0	0	0	0	3	0	7	0	ND	10	0.02
Bloater	ND	ND	ND	0	0	3	3	0	0	0	0	ND	6	0.01
Johnny darter	ND	ND	ND	0	2	1	0	1	1	0	0	ND	5	0.01
Common carp	ND	ND	ND	0	2	0	1	0	2	0	0	ND	5	0.01
Lake trout	ND	ND	ND	1	0	0	0	0	0	1	0	ND	2	<0.01
Spotfin shiner	ND	ND	ND	0	0	0	0	0	2	0	0	ND	2	<0.01
Golden shiner	ND	ND	ND	0	0	0	2	0	0	0	0	ND	2	<0.01
Blackchin shiner	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Channel catfish	ND	ND	ND	0	0	0	1	0	0	0	0	ND	1	<0.01
Longnose sucker	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Brook silverside	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Ninespine stickleback	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Burbot	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Gizzard shad	ND	ND	ND	0	0	0	0	0	0	0	1	ND	1	<0.01
Fathead minnow	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Totals	ND	ND	ND	104	141	9500	16614	7477	3849	18864	29	ND	56578	

Appendix 15. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1979. ND = no data.

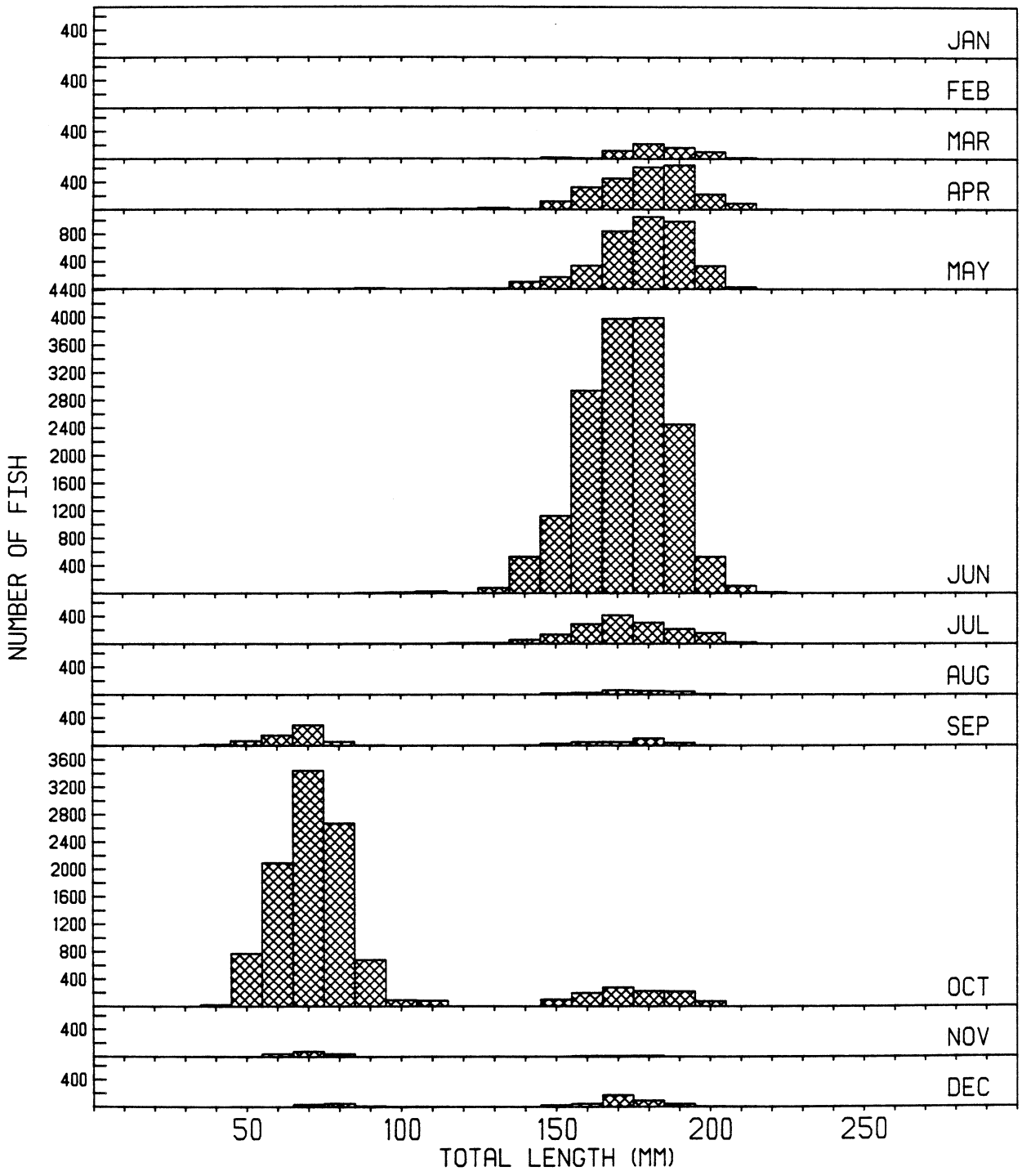
Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	2	1	121	108	16381	65916	52792	ND	ND	135321	86.70
Spottail shiner	ND	ND	ND	108	410	885	8271	163	7874	422	ND	ND	18133	11.62
Yellow perch	ND	ND	ND	1	0	0	428	29	687	0	ND	ND	1145	0.73
Bloater	ND	ND	ND	0	0	0	0	0	482	25	ND	ND	507	0.33
Rainbow smelt	ND	ND	ND	26	236	1	0	3	3	67	ND	ND	336	0.22
Chinook salmon	ND	ND	ND	122	77	58	1	0	0	0	ND	ND	258	0.17
Trout-perch	ND	ND	ND	22	4	21	26	4	2	1	ND	ND	80	0.05
White sucker	ND	ND	ND	38	6	1	7	5	0	1	ND	ND	58	0.04
Johnny darter	ND	ND	ND	0	0	0	21	0	37	0	ND	ND	58	0.04
Coho salmon	ND	ND	ND	28	26	0	0	0	0	0	ND	ND	54	0.04
Slimy sculpin	ND	ND	ND	27	0	0	0	0	0	4	ND	ND	31	0.02
Brown trout	ND	ND	ND	5	4	3	8	0	0	3	ND	ND	23	0.02
Common carp	ND	ND	ND	10	2	3	2	0	0	0	ND	ND	17	0.01
Gizzard shad	ND	ND	ND	3	0	1	0	0	0	10	ND	ND	14	0.01
Emerald shiner	ND	ND	ND	7	1	3	0	0	0	0	ND	ND	11	0.01
Lake trout	ND	ND	ND	0	0	0	0	0	0	10	ND	ND	10	0.01
Rainbow trout	ND	ND	ND	2	1	1	0	1	1	2	ND	ND	8	0.01
Longnose dace	ND	ND	ND	3	0	0	0	0	1	2	ND	ND	6	<0.01
Longnose sucker	ND	ND	ND	0	1	1	2	0	1	0	ND	ND	5	<0.01
Burbot	ND	ND	ND	0	0	1	0	2	0	0	ND	ND	3	<0.01
Spotfin shiner	ND	ND	ND	0	0	0	0	2	0	1	ND	ND	3	<0.01
Sand shiner	ND	ND	ND	0	0	0	0	0	0	3	ND	ND	3	<0.01
Northern pike	ND	ND	ND	0	0	0	0	0	2	0	ND	ND	2	<0.01
Fathead minnow	ND	ND	ND	0	0	1	0	1	0	0	ND	ND	2	<0.01
Bluntnose minnow	ND	ND	ND	0	1	0	0	0	0	0	ND	ND	1	<0.01
Ninespine stickleback	ND	ND	ND	0	0	1	0	0	0	0	ND	ND	1	<0.01
Black crappie	ND	ND	ND	0	1	0	0	0	0	0	ND	ND	1	<0.01
Green sunfish	ND	ND	ND	0	0	1	0	0	0	0	ND	ND	1	<0.01
Shorthead redhorse	ND	ND	ND	1	0	0	0	0	0	0	ND	ND	1	<0.01
Lake chub	ND	ND	ND	1	0	0	0	0	0	0	ND	ND	1	<0.01
Bluegill	ND	ND	ND	0	0	1	0	0	0	0	ND	ND	1	<0.01
Totals	ND	ND	ND	406	771	1104	8874	16591	75006	53343	ND	ND	156095	



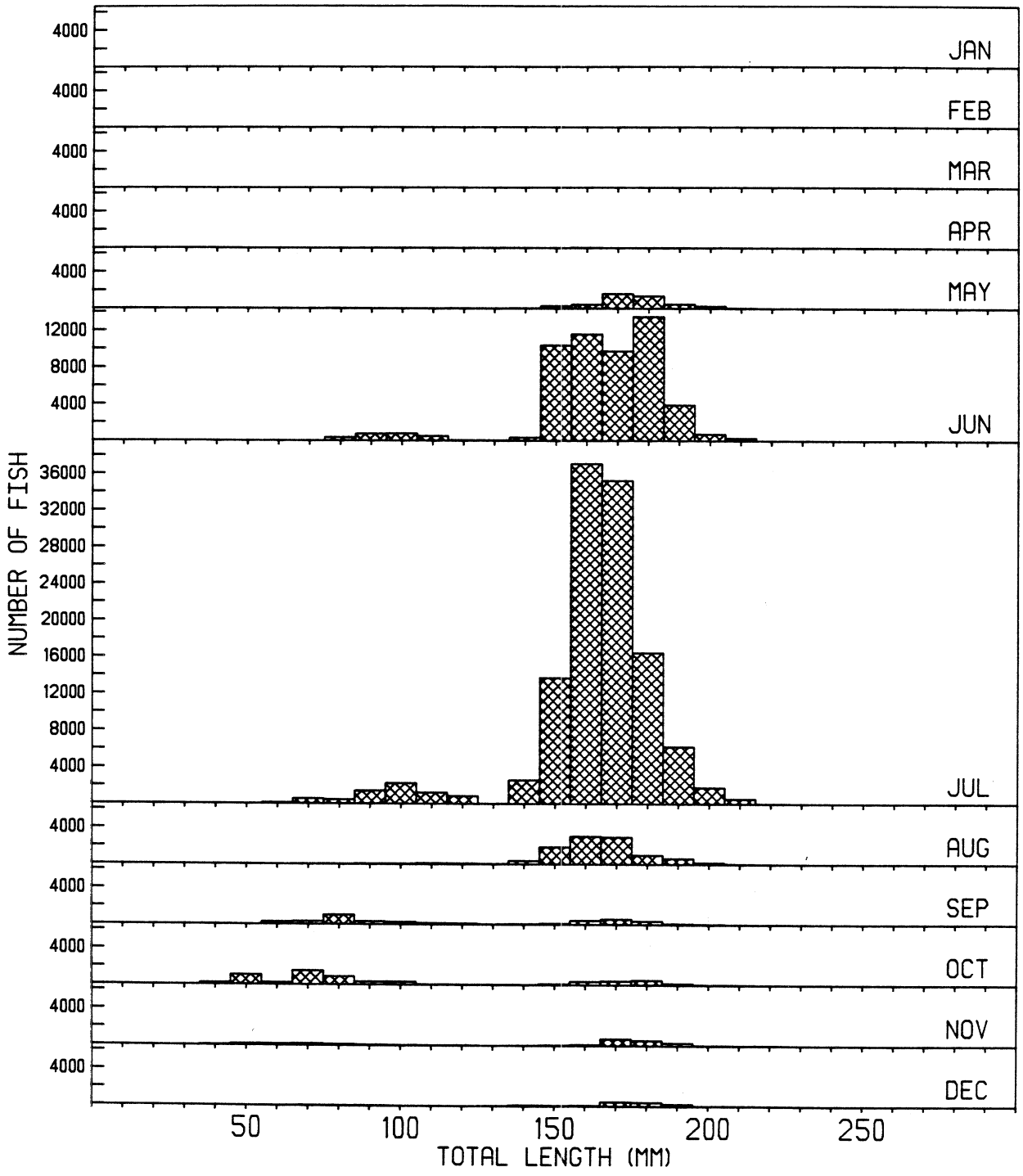
Appendix 16. Length-frequency histograms of alewives impinged during 1975 at the Cook Plant, southeastern Lake Michigan.



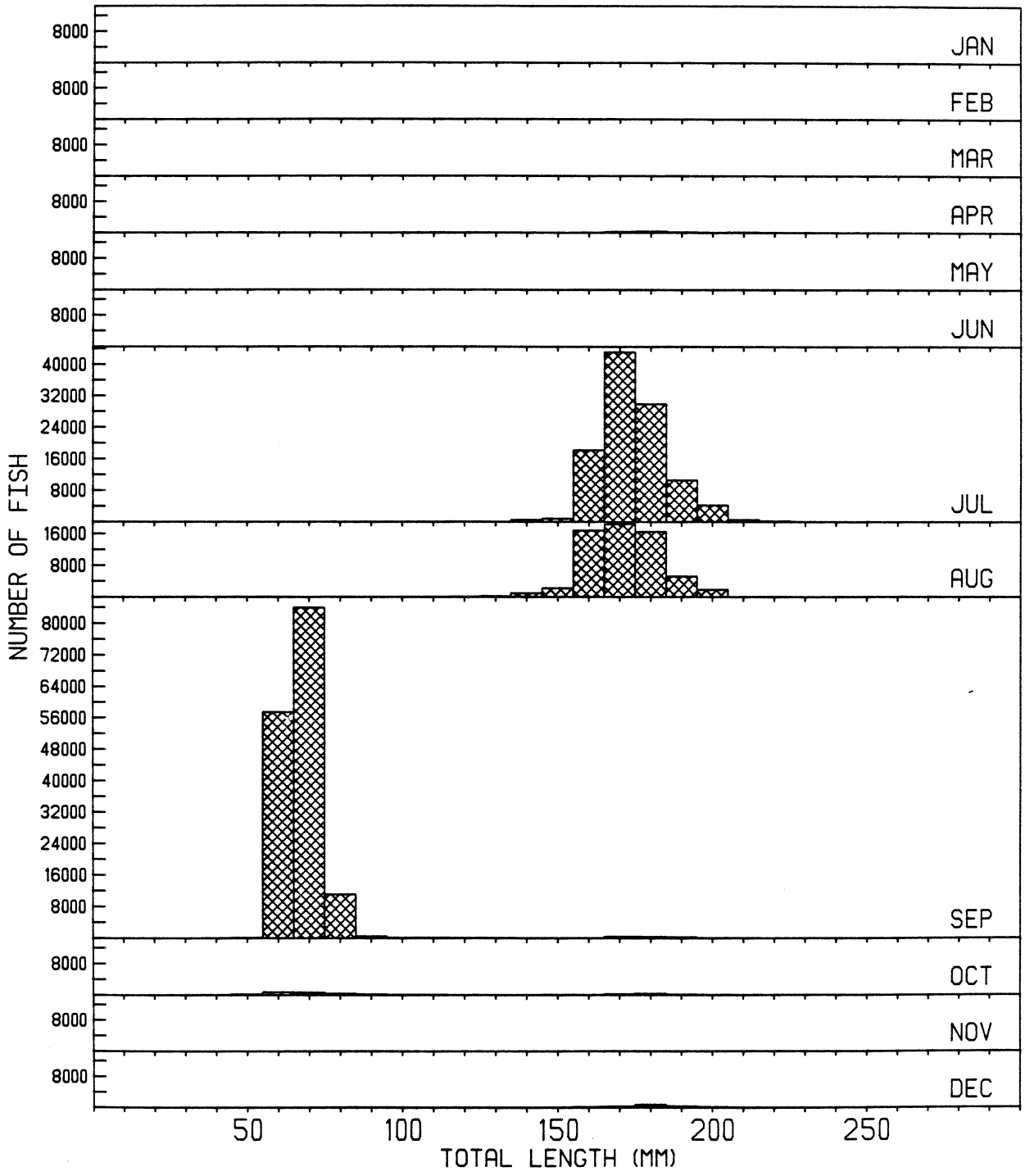
Appendix 17. Length-frequency histograms of alewives impinged during 1976 at the Cook Plant, southeastern Lake Michigan.



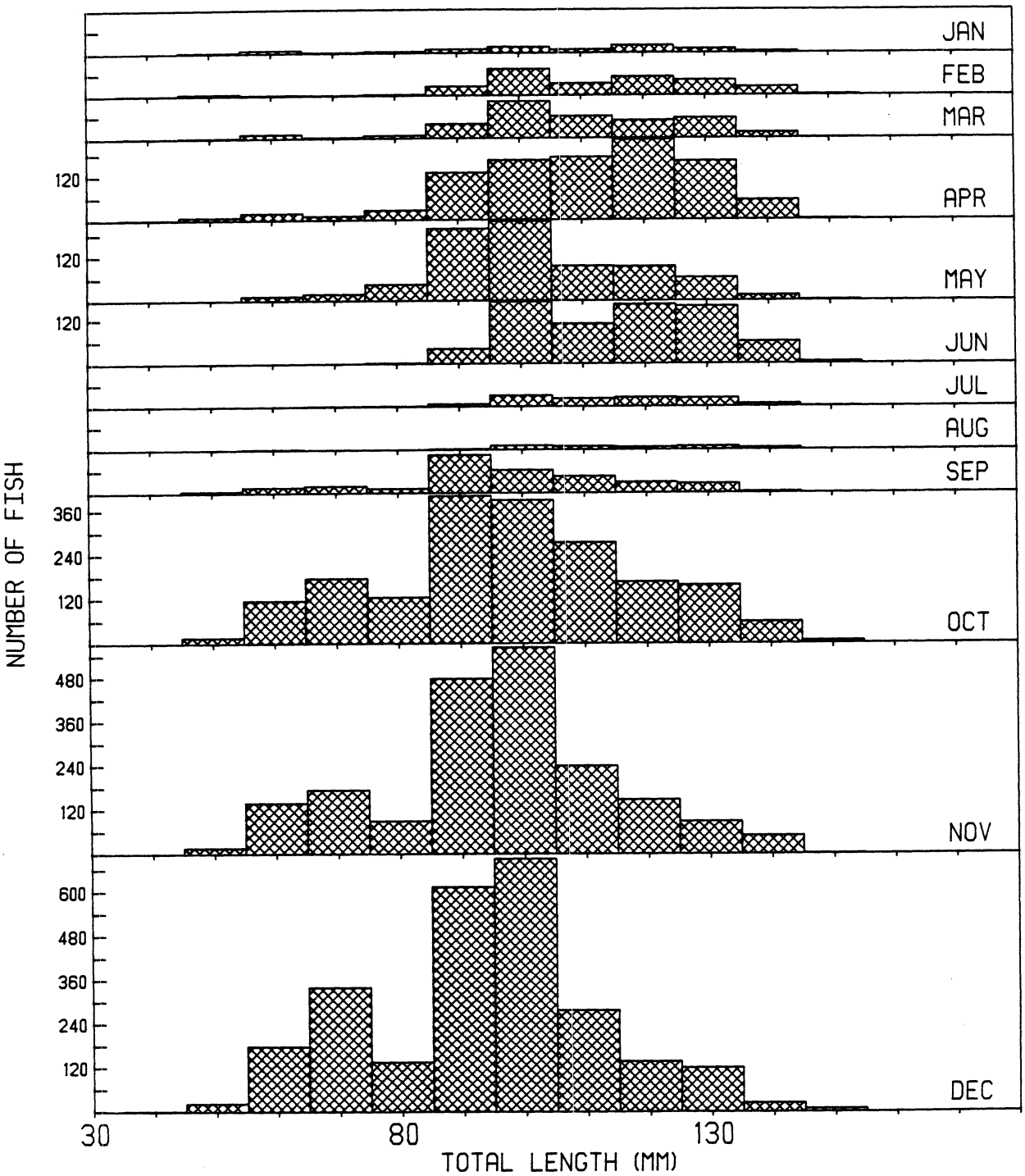
Appendix 18. Length-frequency histograms of alewives impinged during 1977 at the Cook Plant, southeastern Lake Michigan.



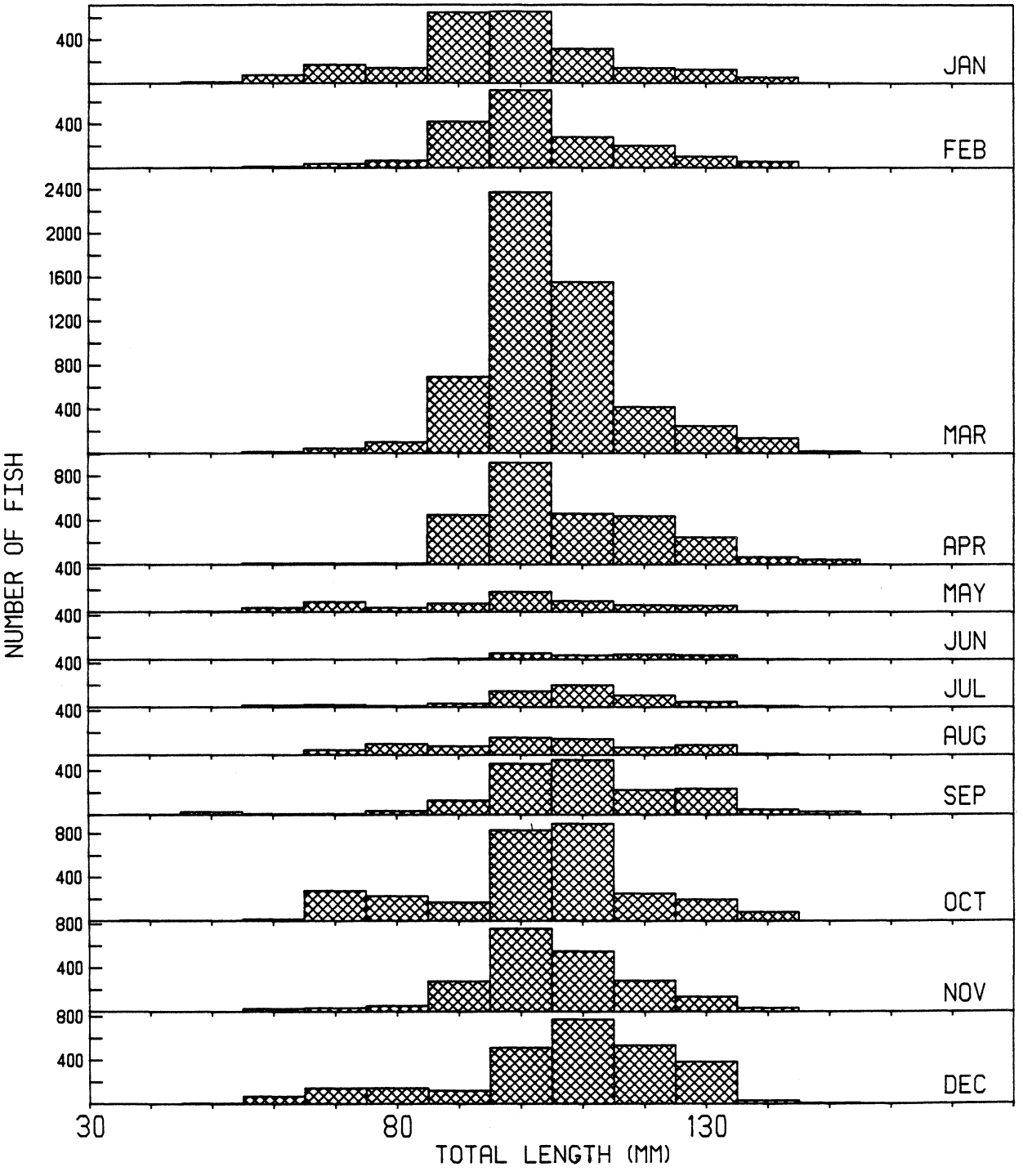
Appendix 19. Length-frequency histograms of alewives impinged during 1978 at the Cook Plant, southeastern Lake Michigan.



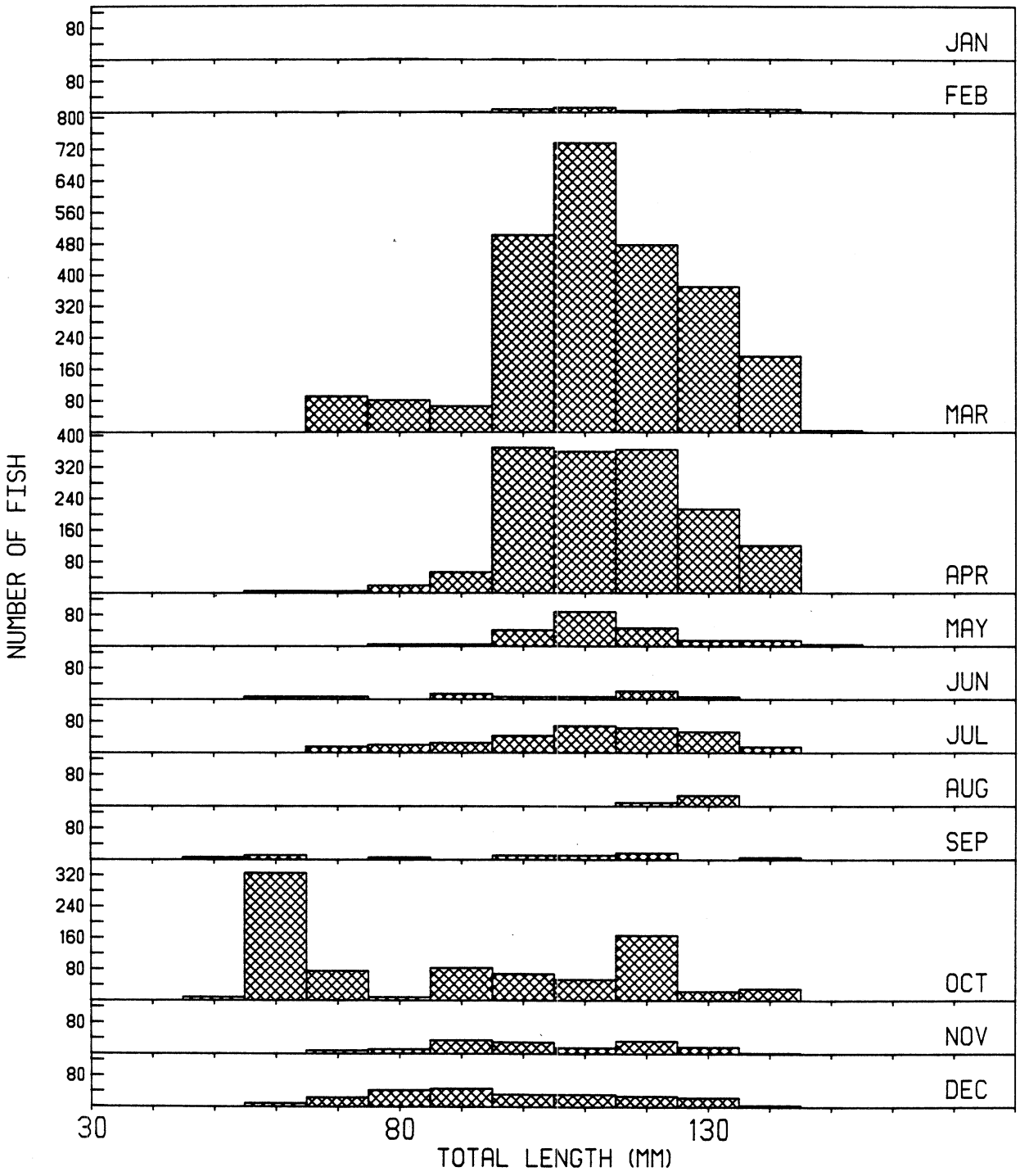
Appendix 20. Length-frequency histograms of alewives impinged during 1979 at the Cook Plant, southeastern Lake Michigan.



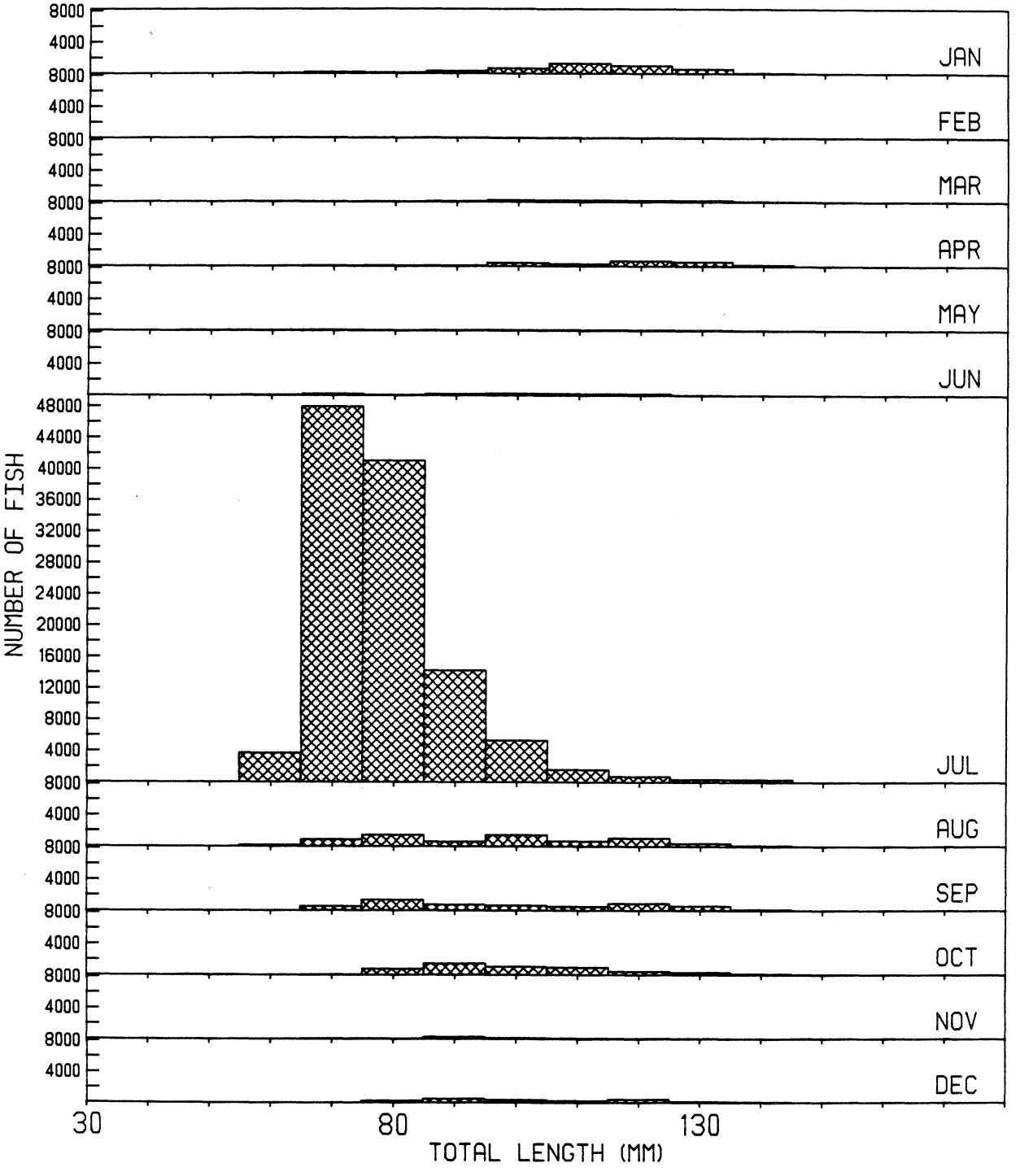
Appendix 21. Length-frequency histograms of spottail shiners impinged during 1975 at the Cook Plant, southeastern Lake Michigan.



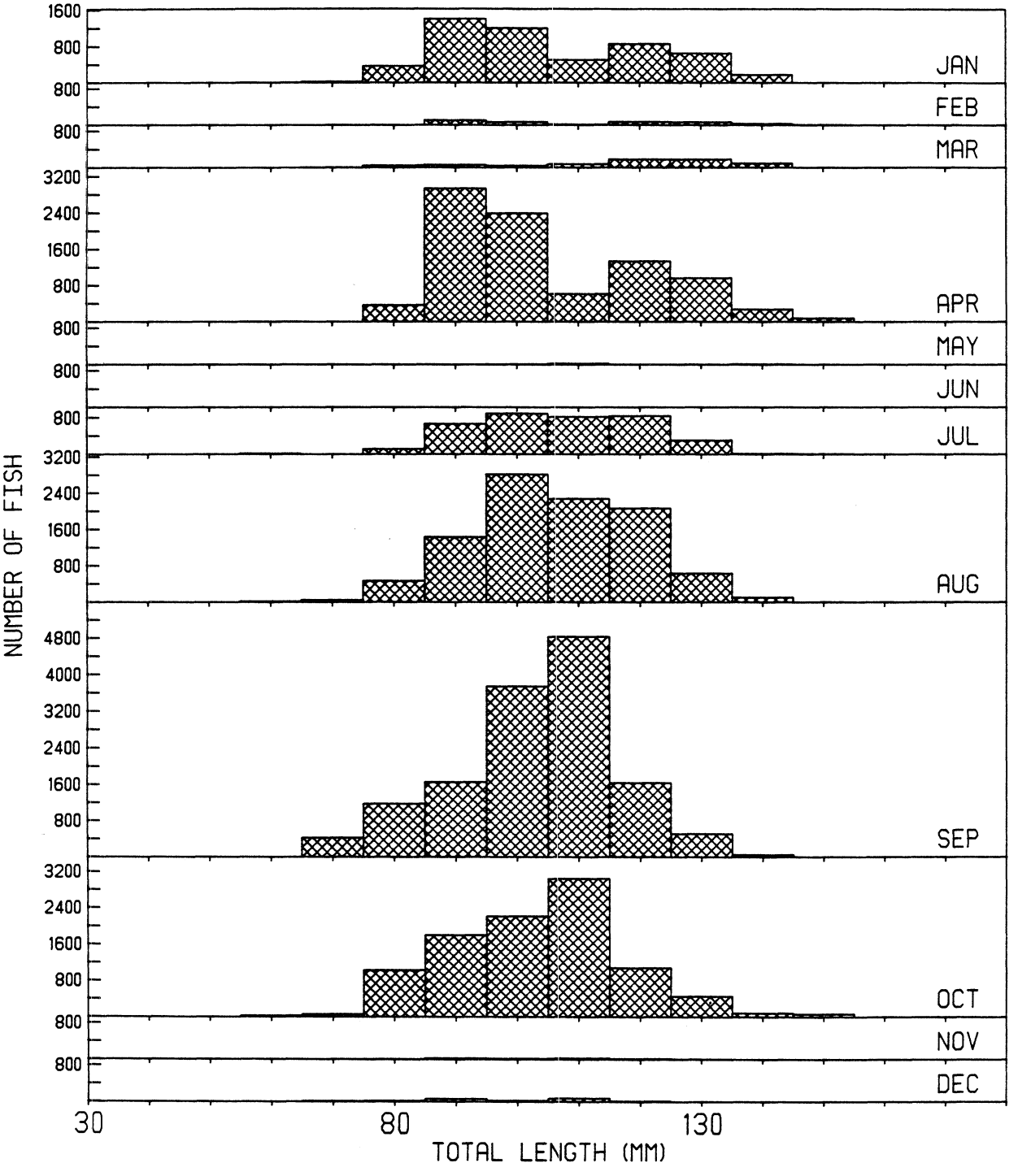
Appendix 22. Length-frequency histograms of spottail shiners impinged during 1976 at the Cook Plant, southeastern Lake Michigan.



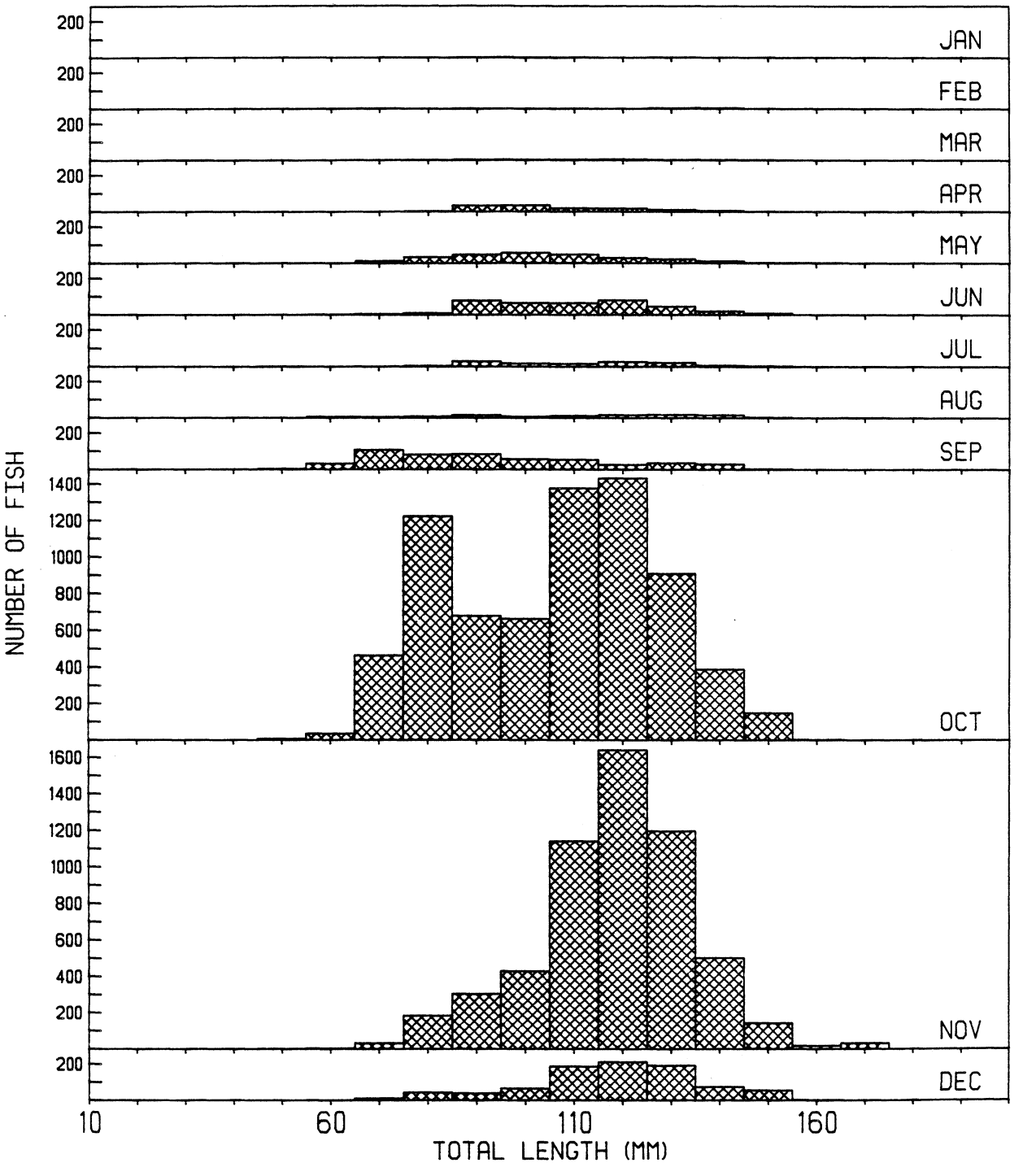
Appendix 23. Length-frequency histograms of spottail shiners impinged during 1977 at the Cook Plant, southeastern Lake Michigan.



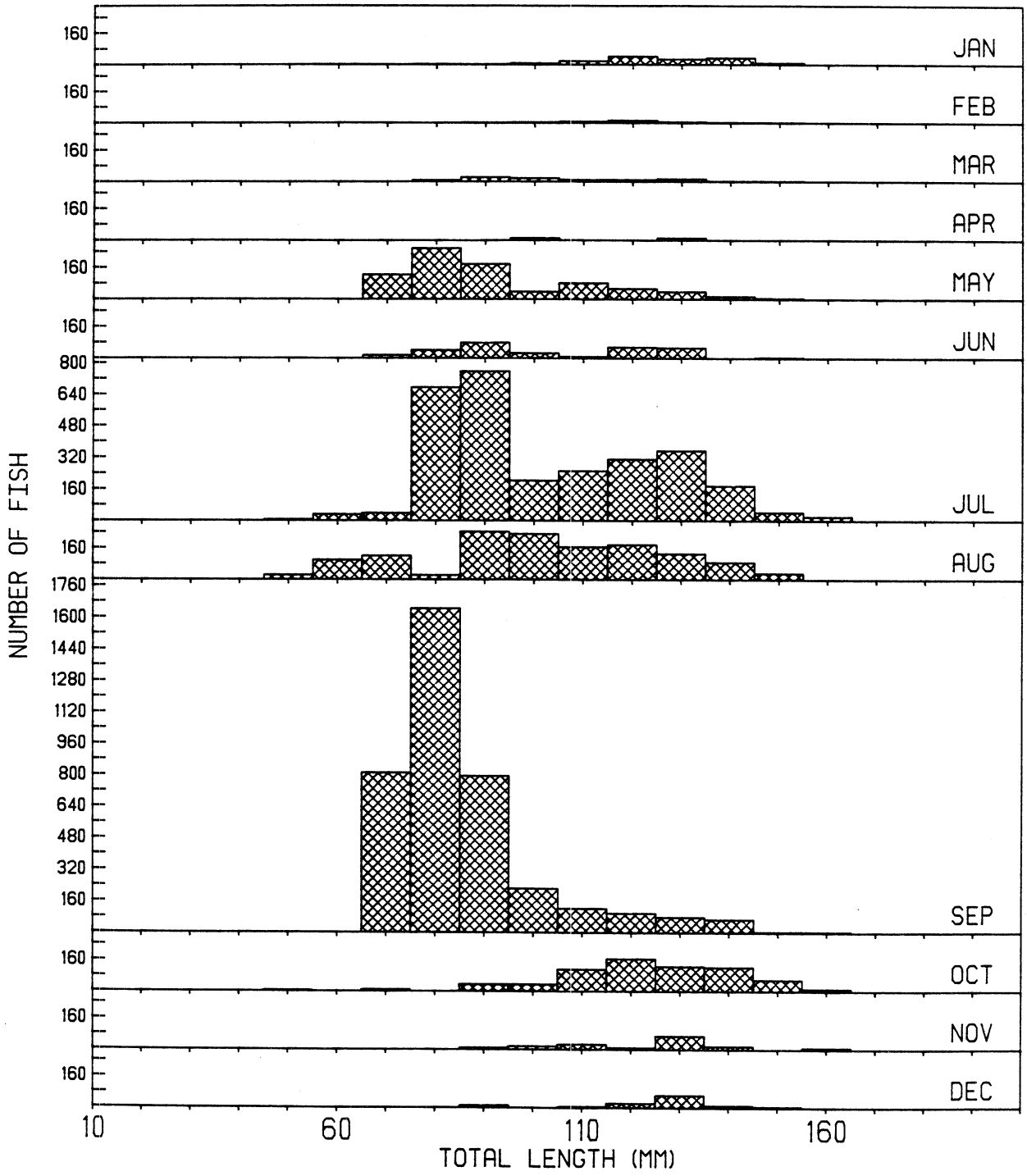
Appendix 24. Length-frequency histograms of spottail shiners impinged during 1978 at the Cook Plant, southeastern Lake Michigan.



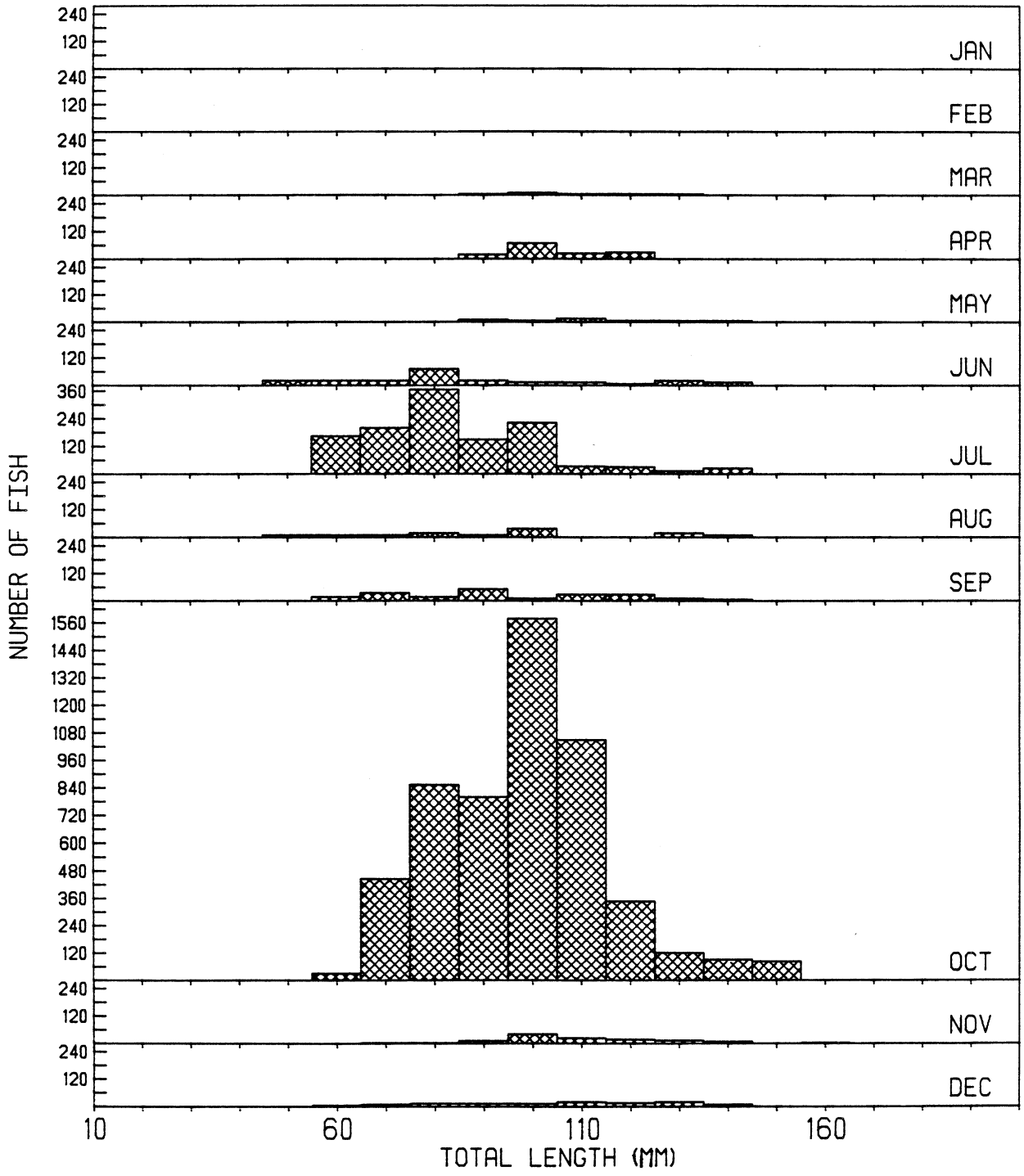
Appendix 25. Length-frequency histograms of spottail shiners impinged during 1979 at the Cook Plant, southeastern Lake Michigan.



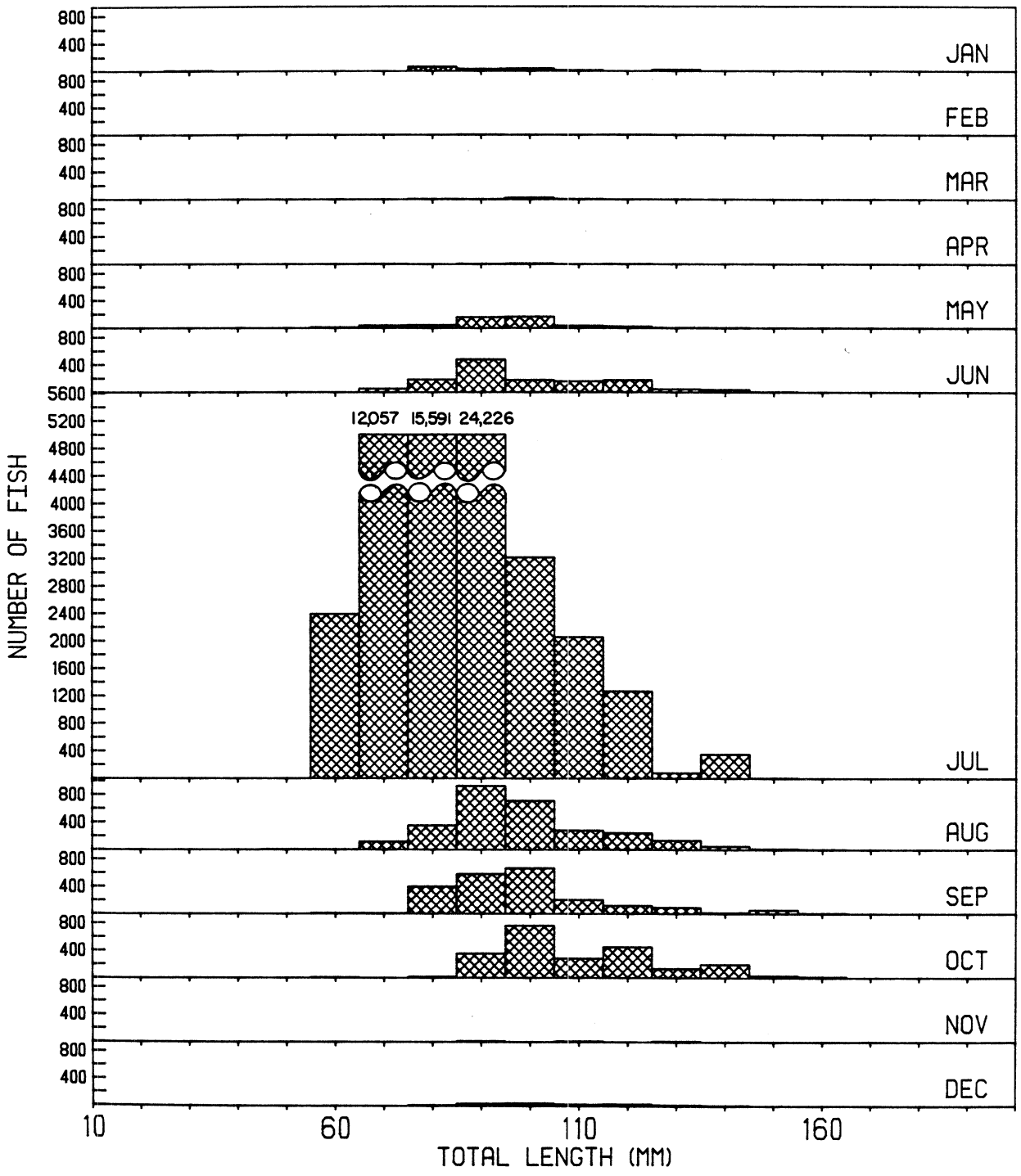
Appendix 26. Length-frequency histograms of trout-perch impinged during 1975 at the Cook Plant, southeastern Lake Michigan.



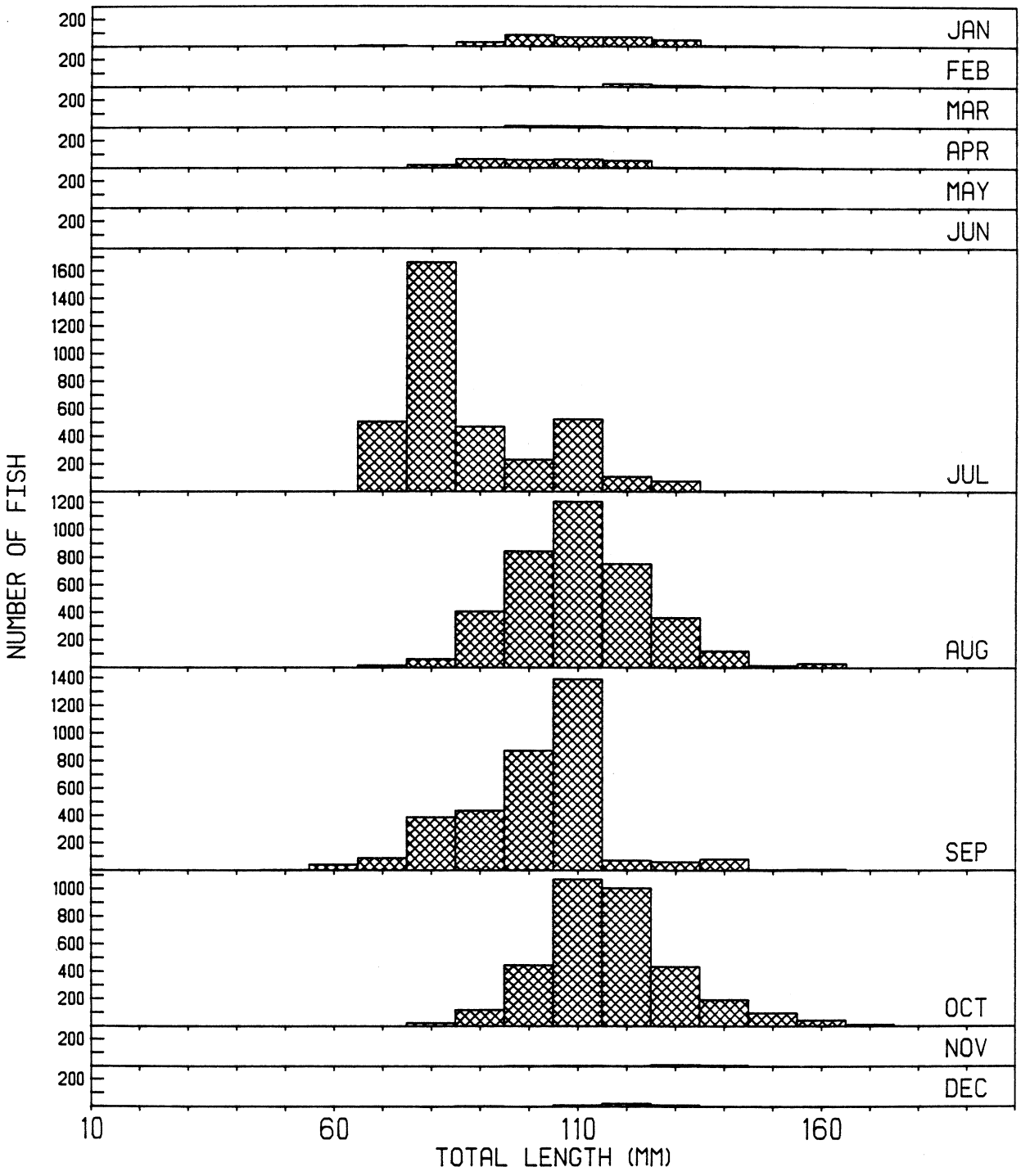
Appendix 27. Length-frequency histograms of trout-perch impinged during 1976 at the Cook Plant, southeastern Lake Michigan.



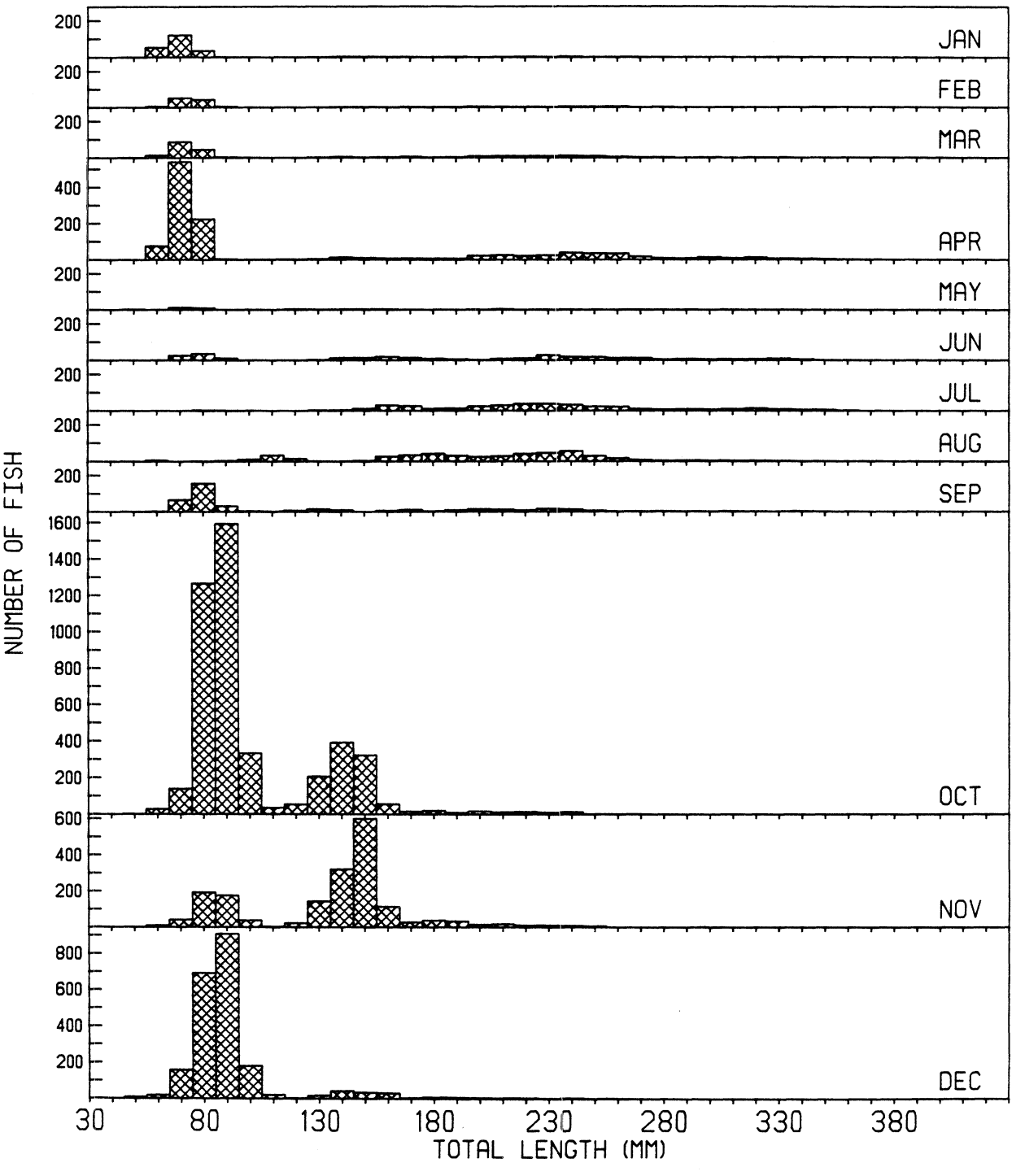
Appendix 28. Length-frequency histograms of trout-perch impinged during 1977 at the Cook Plant, southeastern Lake Michigan.



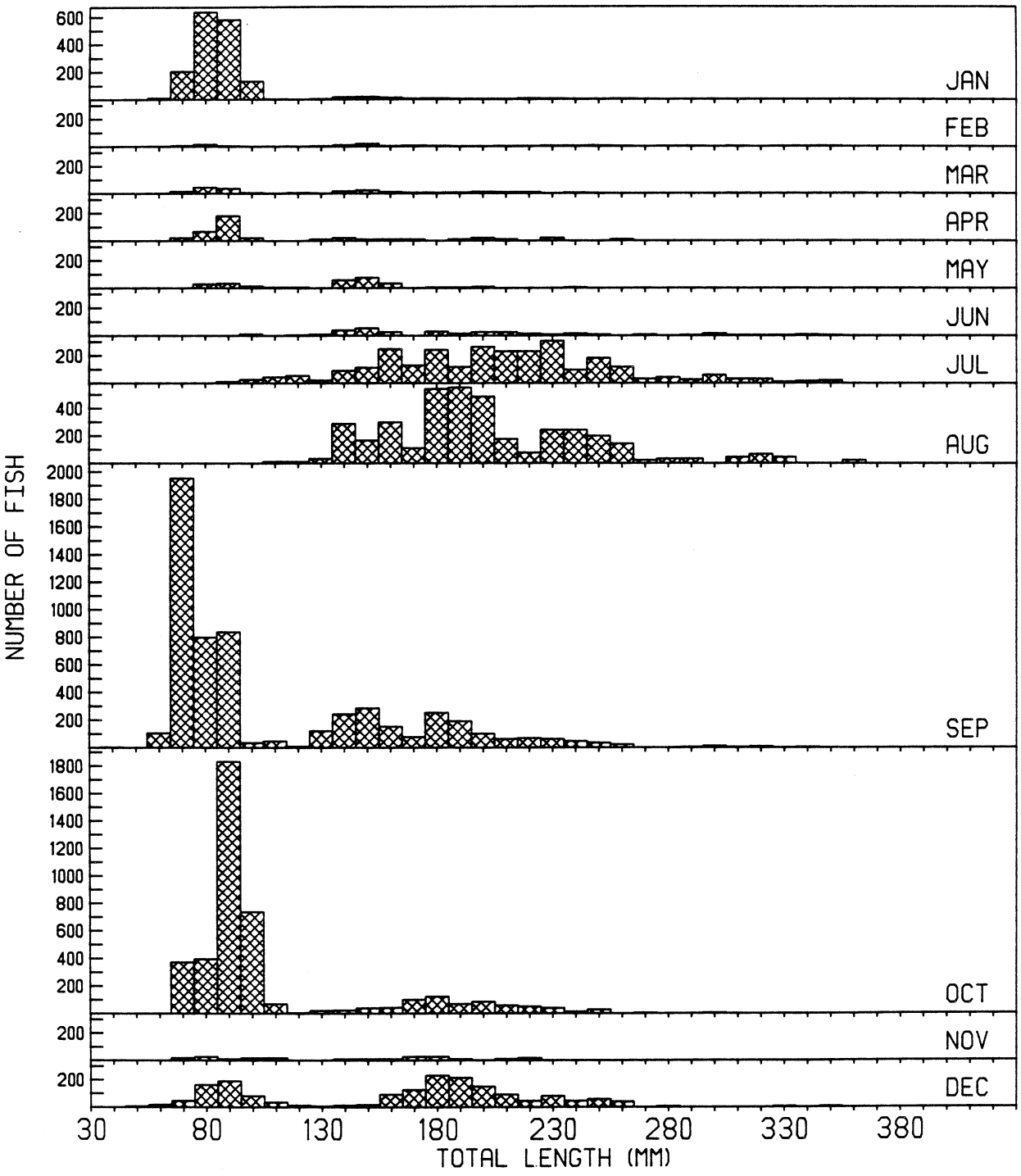
Appendix 29. Length-frequency histograms of trout-perch impinged during 1978 at the Cook Plant, southeastern Lake Michigan.



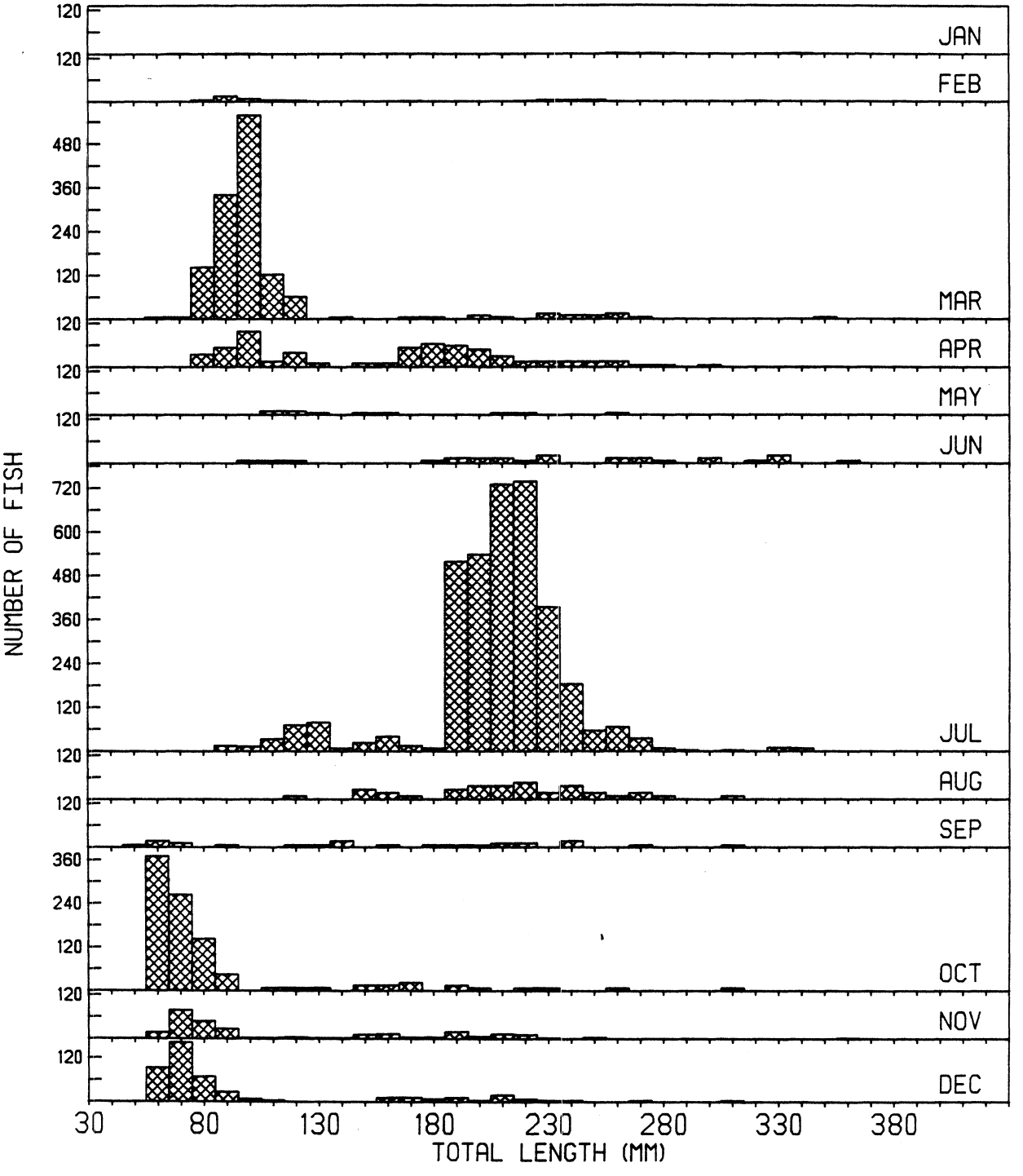
Appendix 30. Length-frequency histograms of trout-perch impinged during 1979 at the Cook Plant, southeastern Lake Michigan.



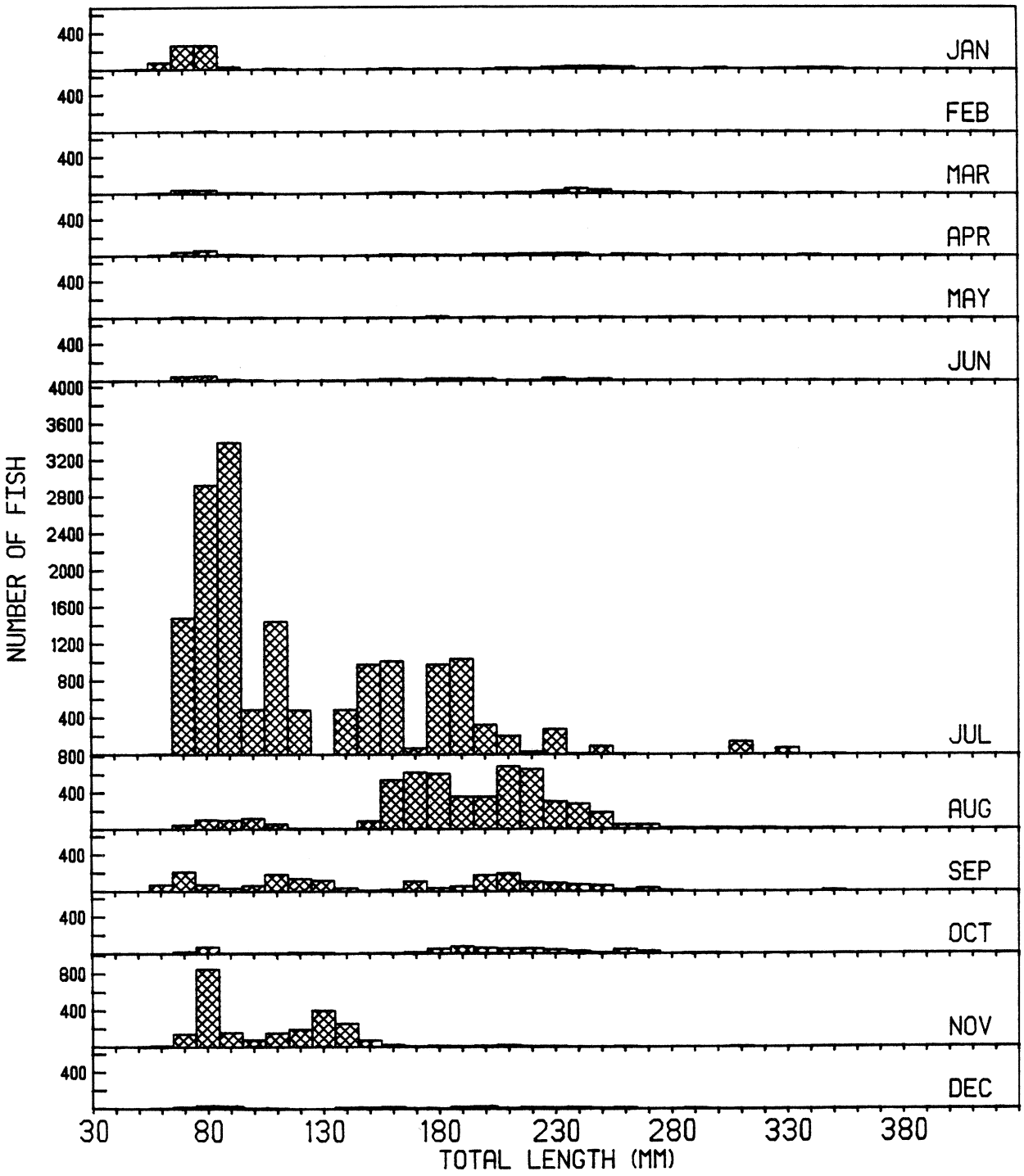
Appendix 31. Length-frequency histograms of yellow perch impinged during 1975 at the Cook Plant, southeastern Lake Michigan.



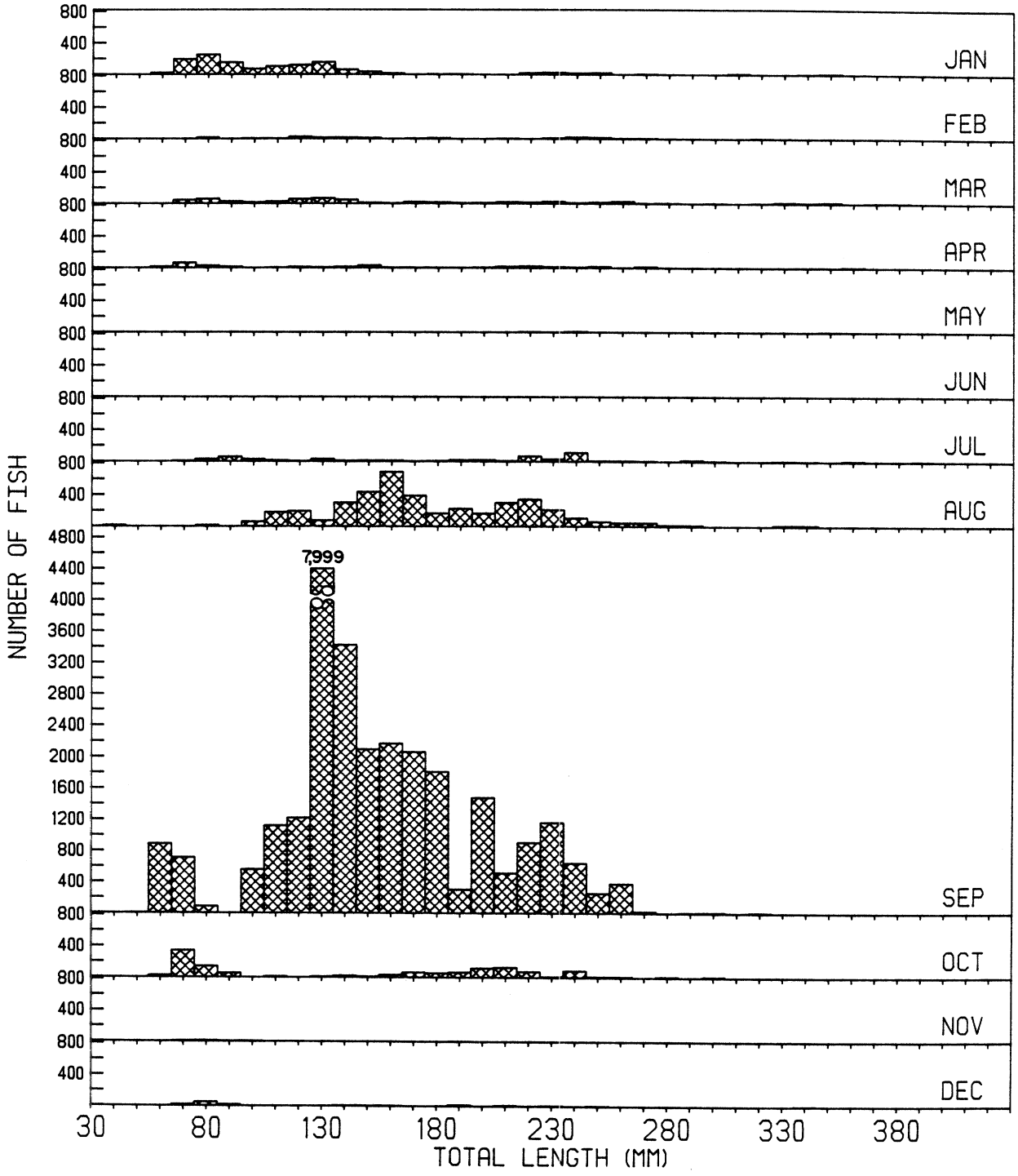
Appendix 32. Length-frequency histograms of yellow perch impinged during 1976 at the Cook Plant, southeastern Lake Michigan.



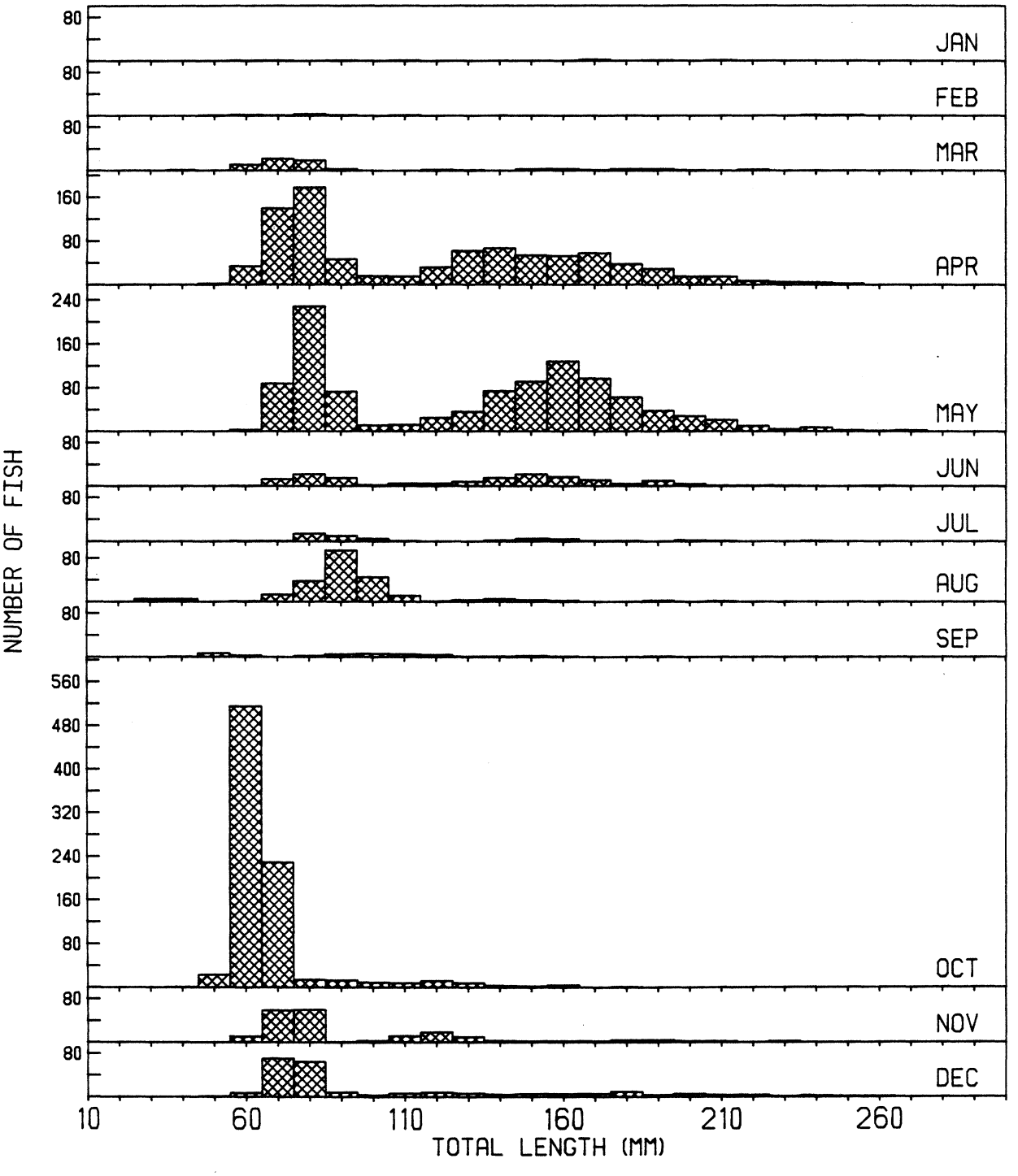
Appendix 33. Length-frequency histograms of yellow perch impinged during 1977 at the Cook Plant, southeastern Lake Michigan.



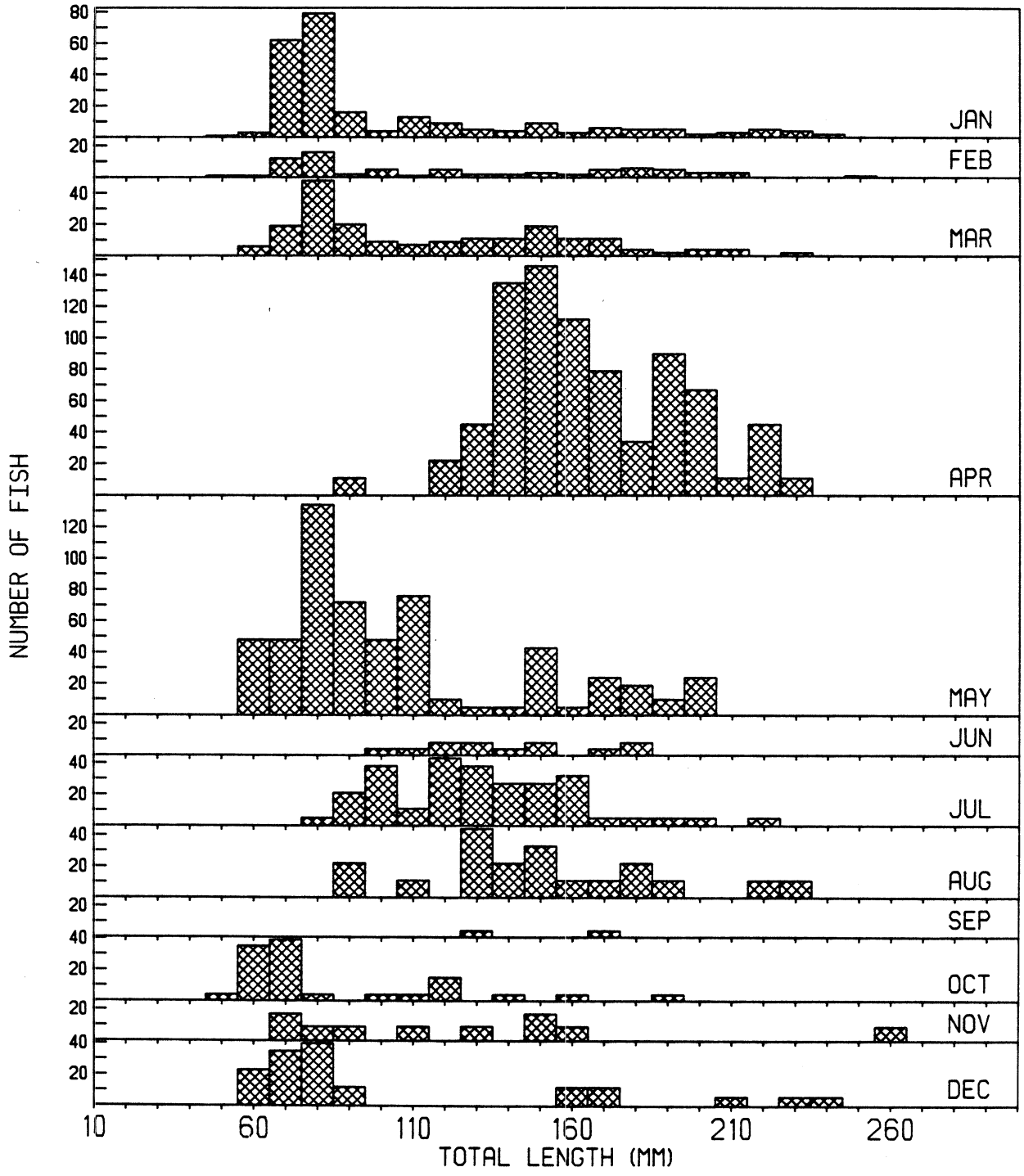
Appendix 34. Length-frequency histograms of yellow perch impinged during 1978 at the Cook Plant, southeastern Lake Michigan.



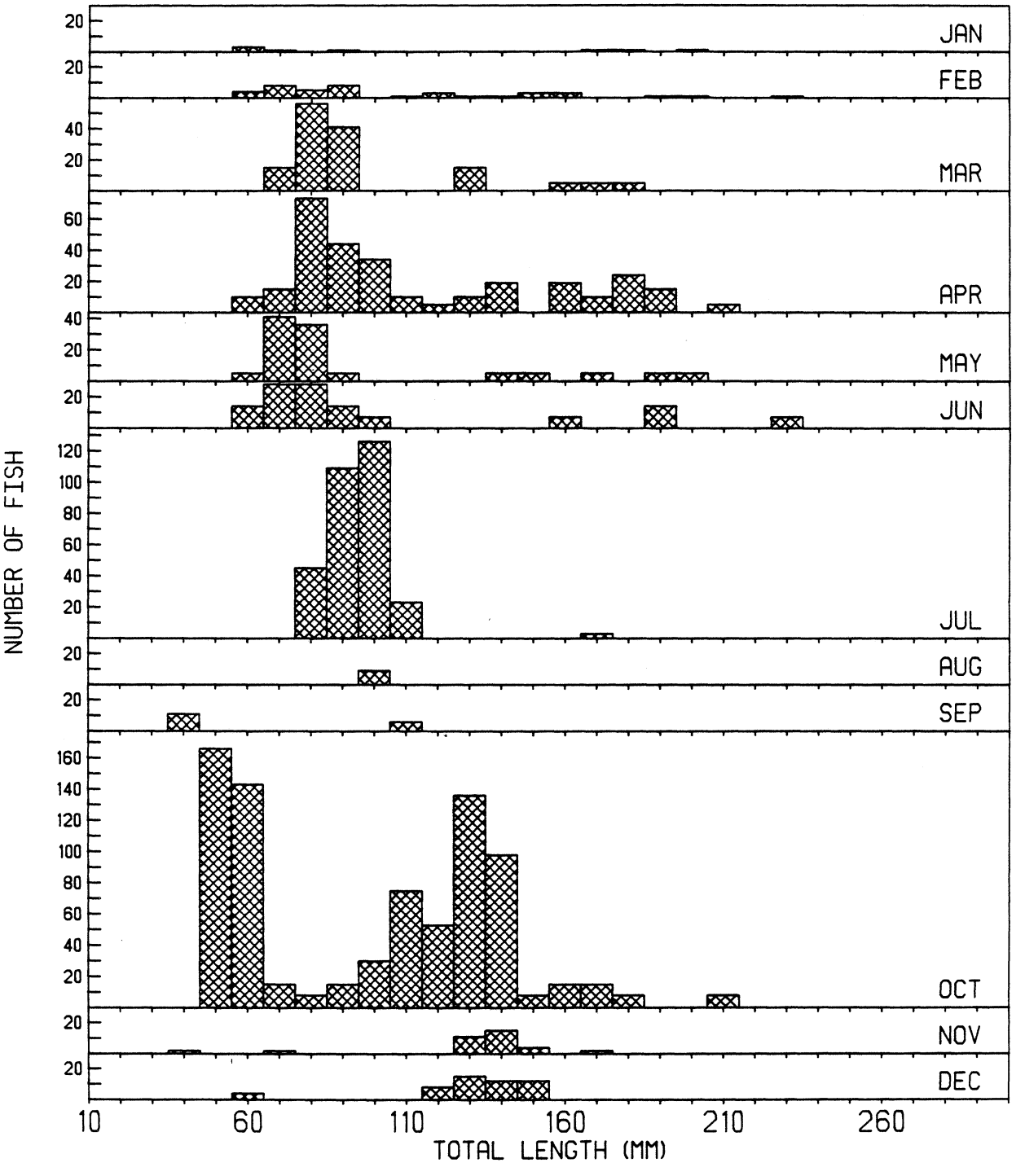
Appendix 35. Length-frequency histograms of yellow perch impinged during 1979 at the Cook Plant, southeastern Lake Michigan.



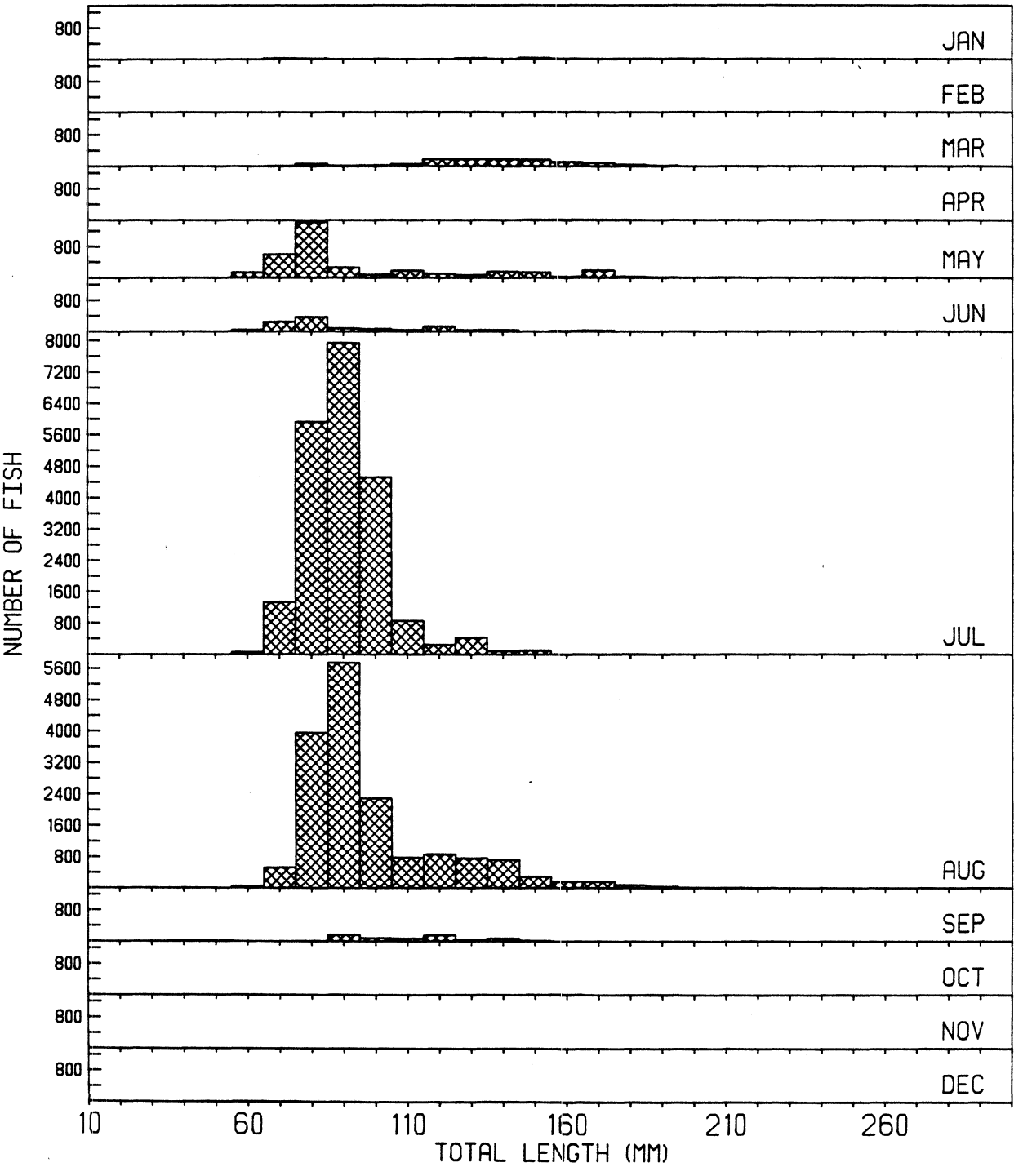
Appendix 36. Length-frequency histograms of rainbow smelt impinged during 1975 at the Cook Plant, southeastern Lake Michigan.



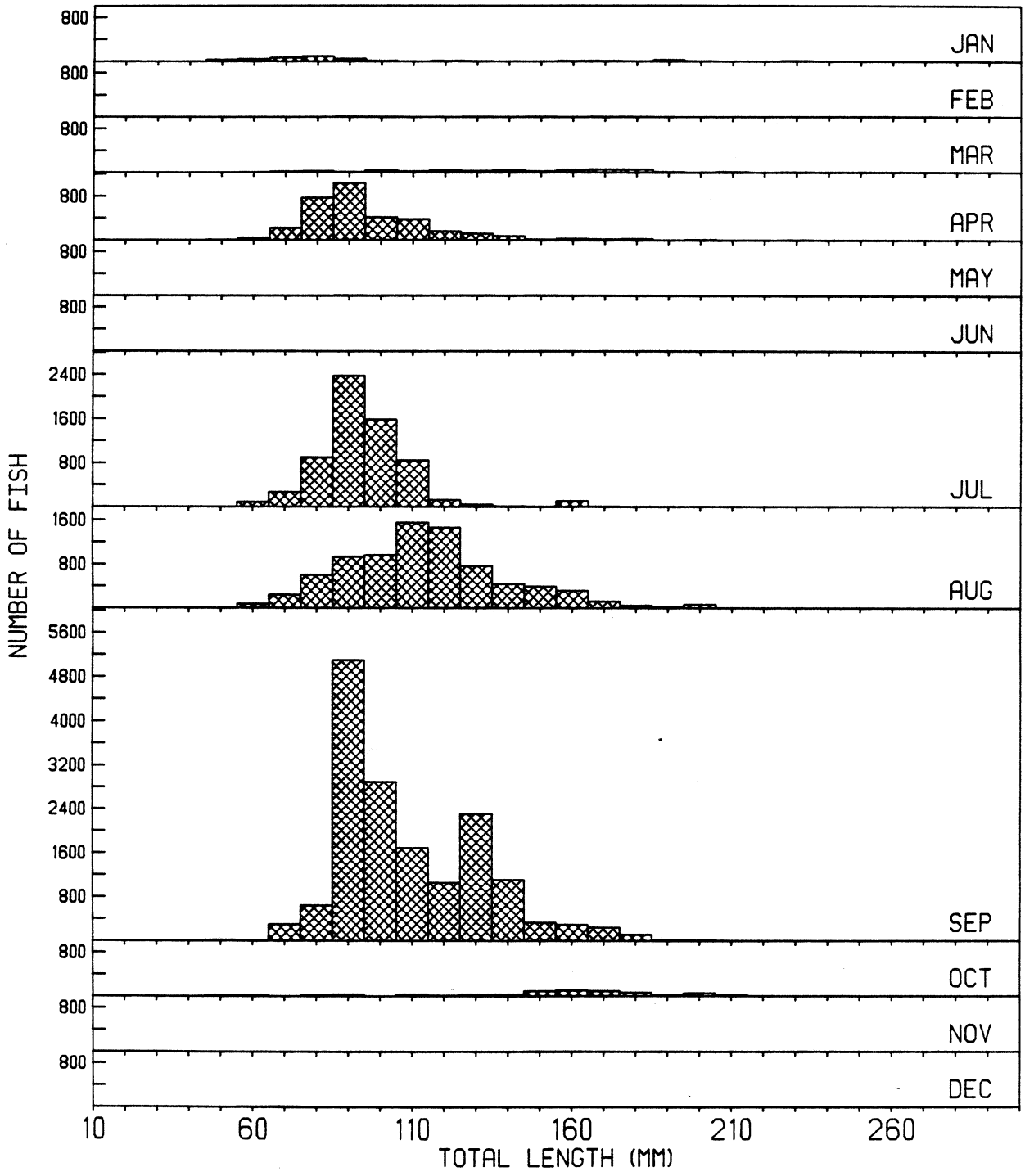
Appendix 37. Length-frequency histograms of rainbow smelt impinged during 1976 at the Cook Plant, southeastern Lake Michigan.



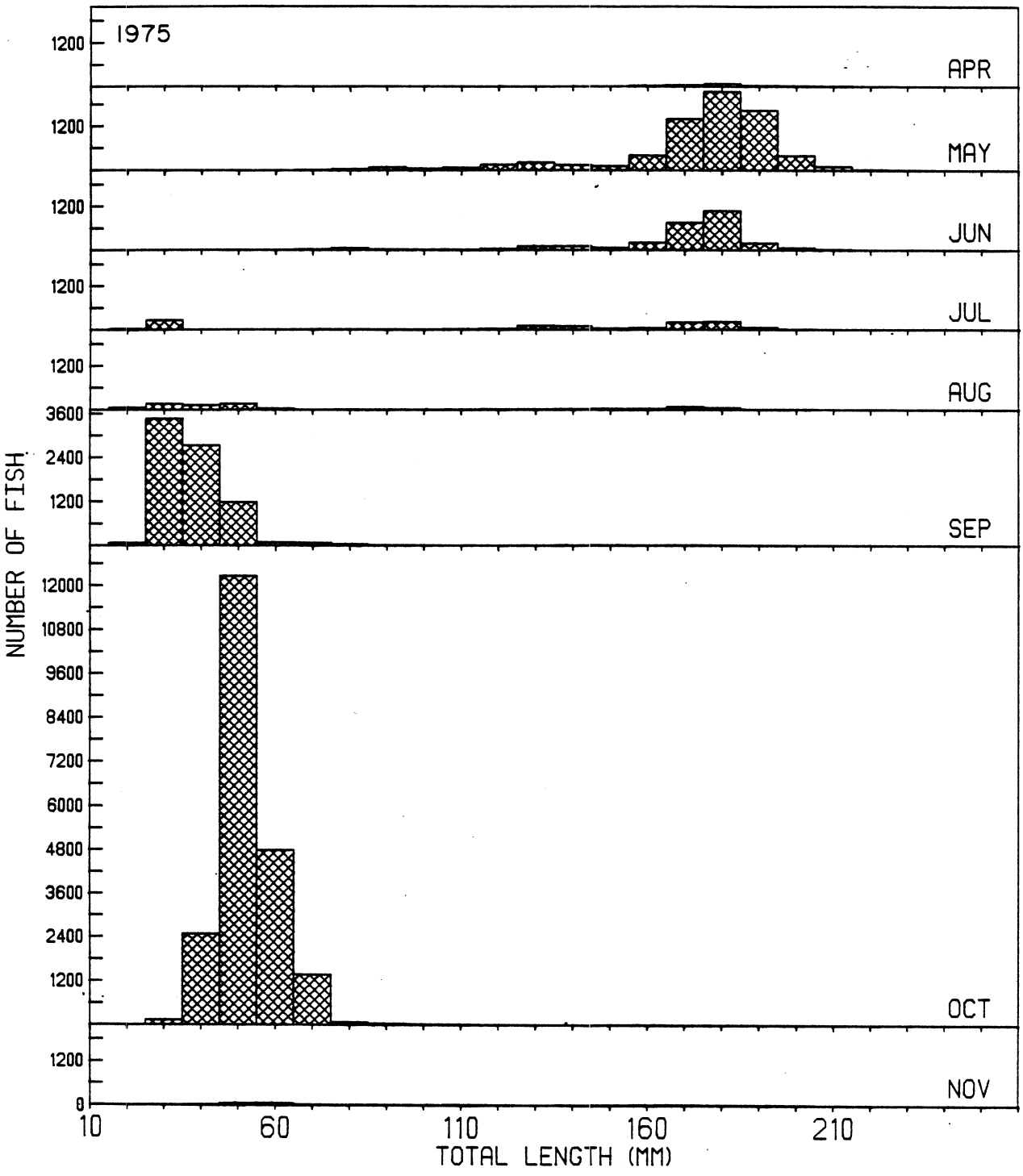
Appendix 38. Length-frequency histograms of rainbow smelt impinged during 1977 at the Cook Plant, southeastern Lake Michigan.



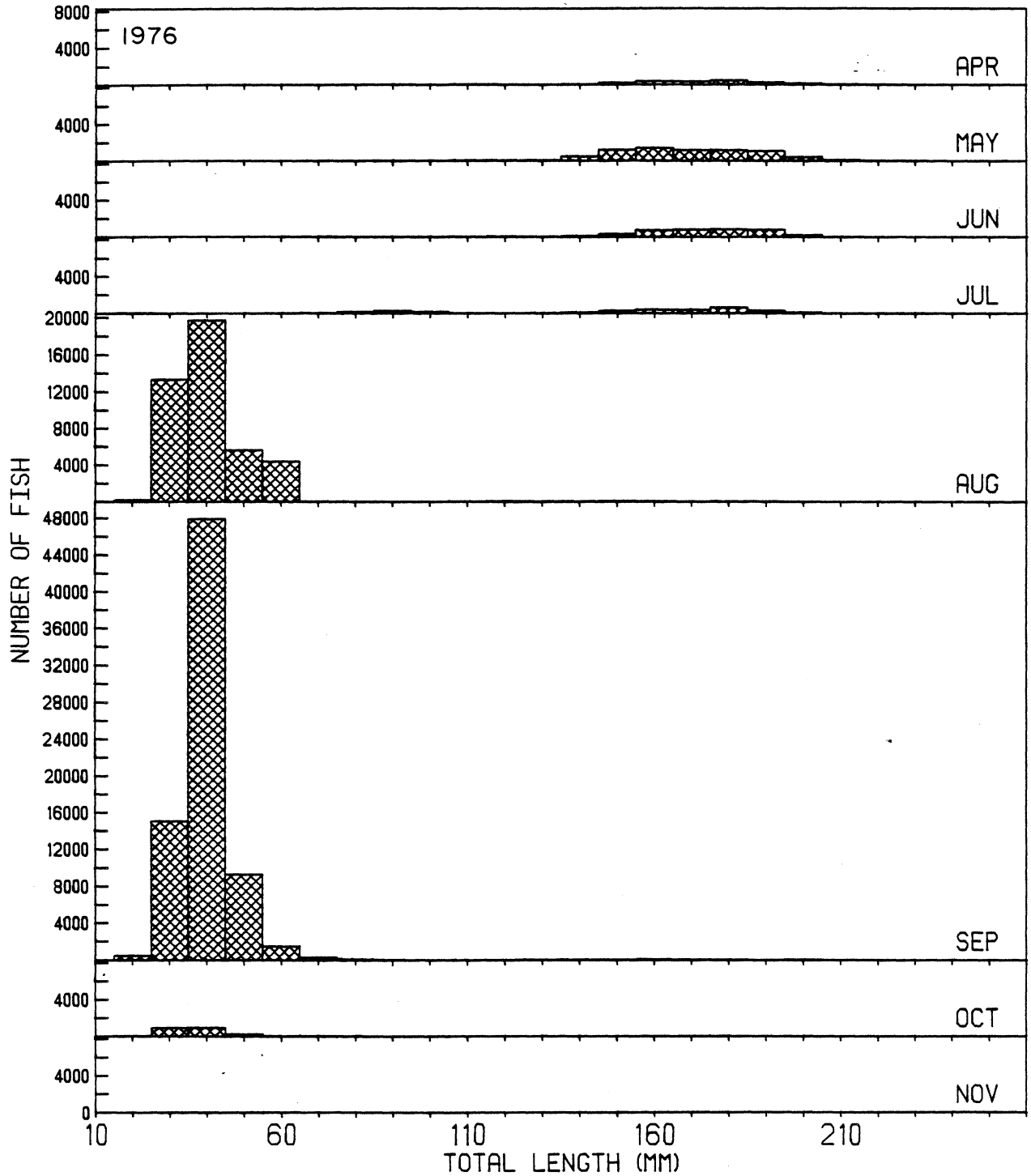
Appendix 39. Length-frequency histograms of rainbow smelt impinged during 1978 at the Cook Plant, southeastern Lake Michigan.



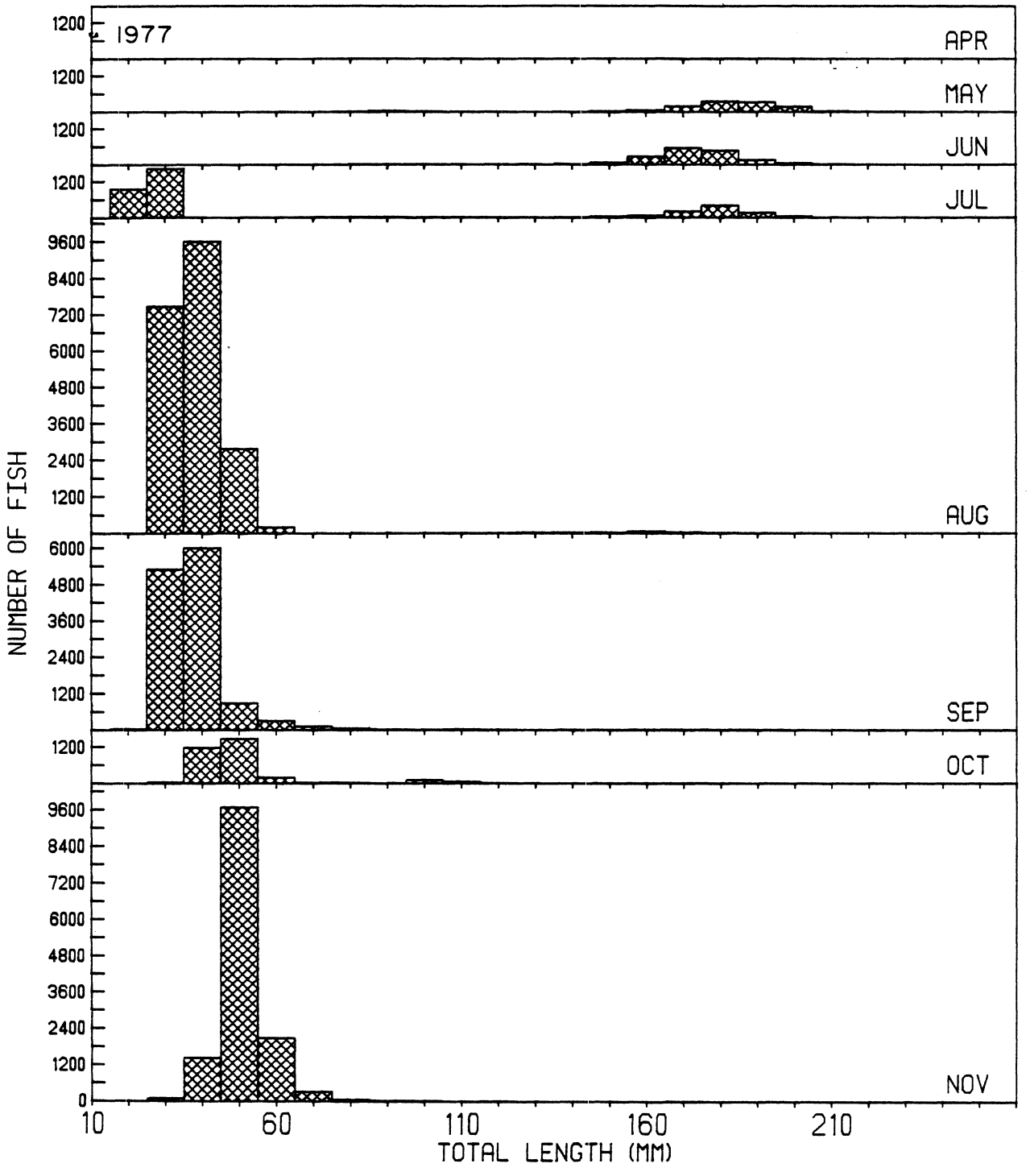
Appendix 40. Length-frequency histograms of rainbow smelt impinged during 1979 at the Cook Plant, southeastern Lake Michigan.



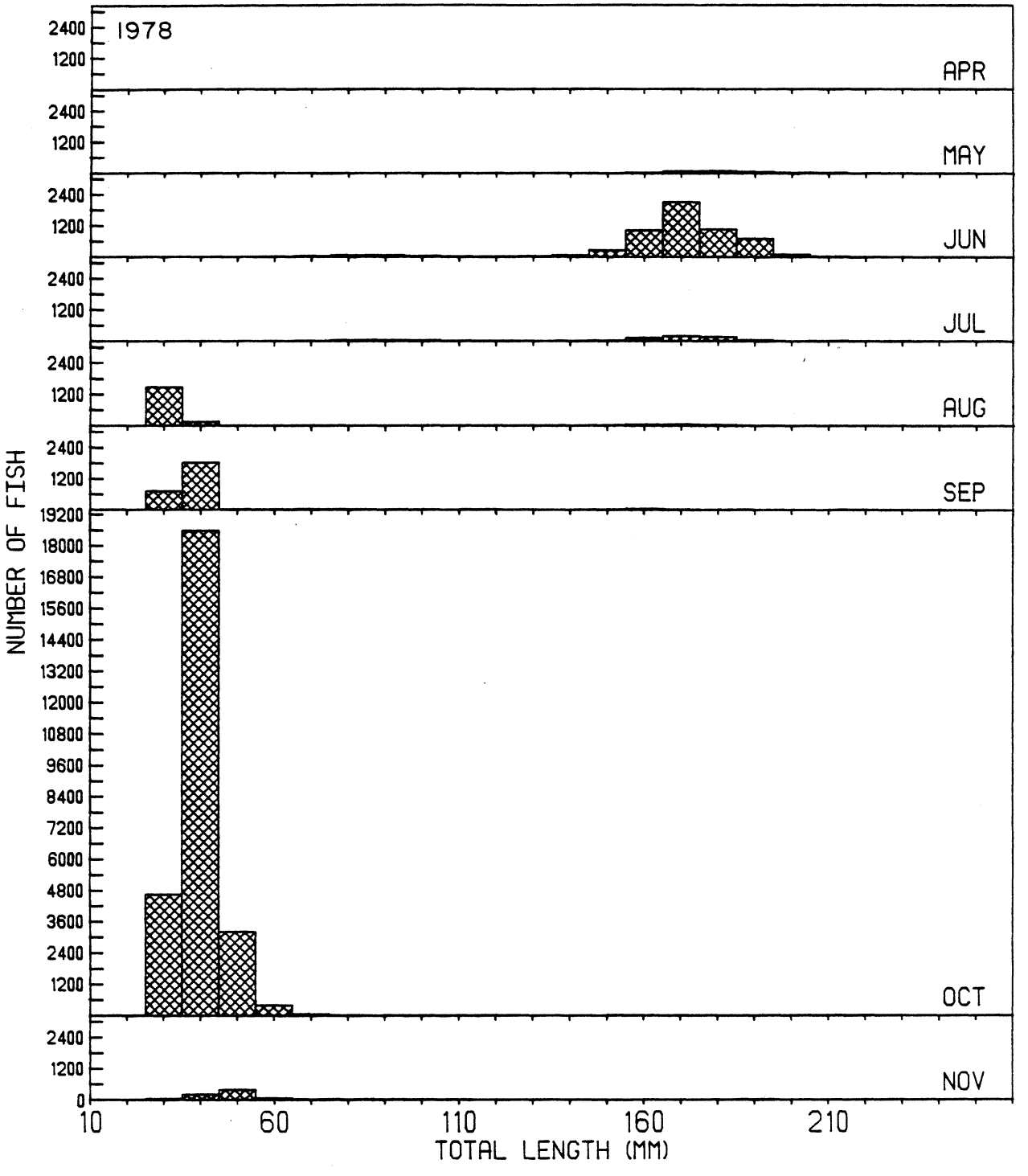
Appendix 41. Length-frequency histograms of alewives caught during 1975 field sampling at the Cook Plant, southeastern Lake Michigan.



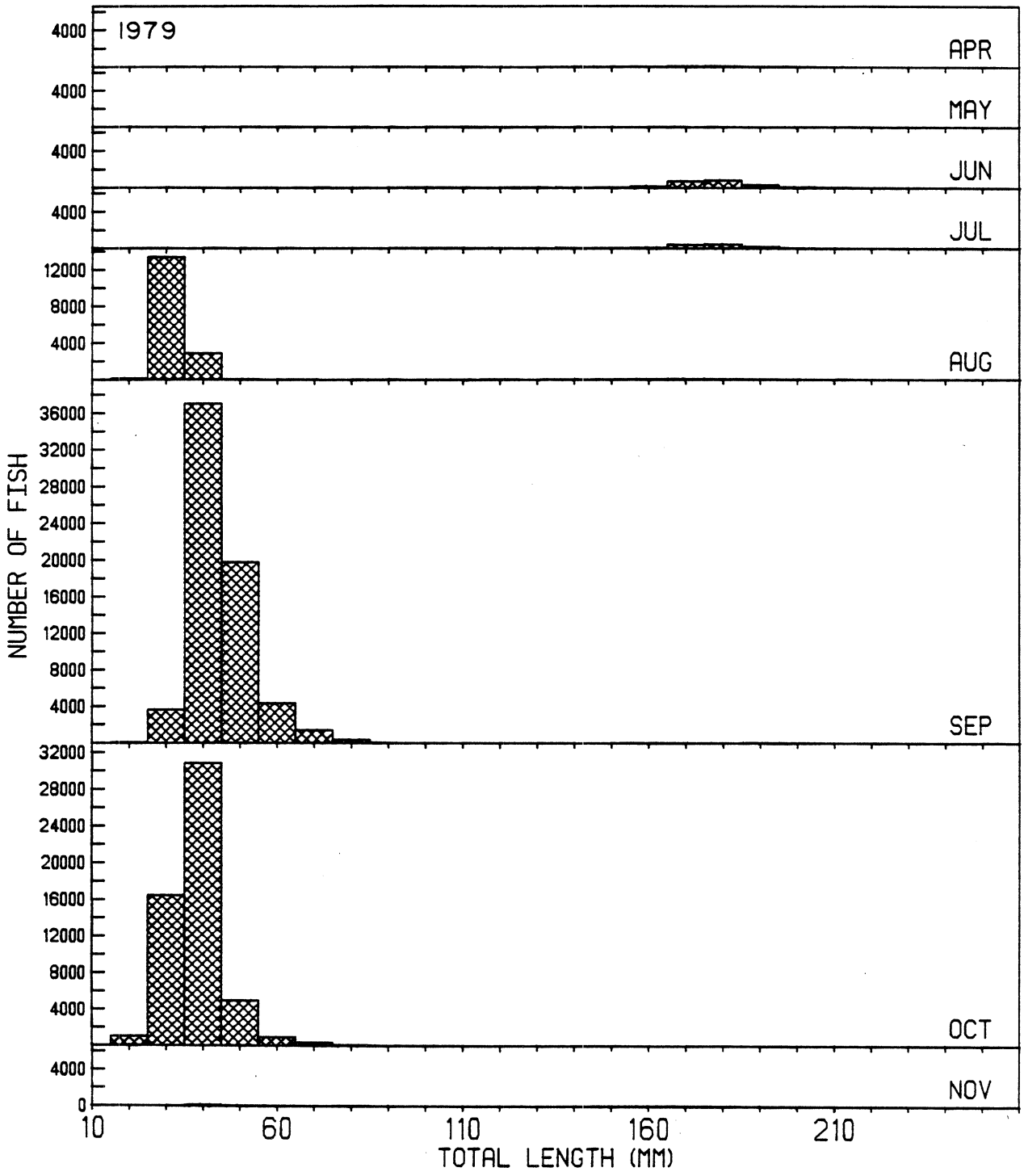
Appendix 42. Length-frequency histograms of alewives caught during 1976 field sampling at the Cook Plant, southeastern Lake Michigan.



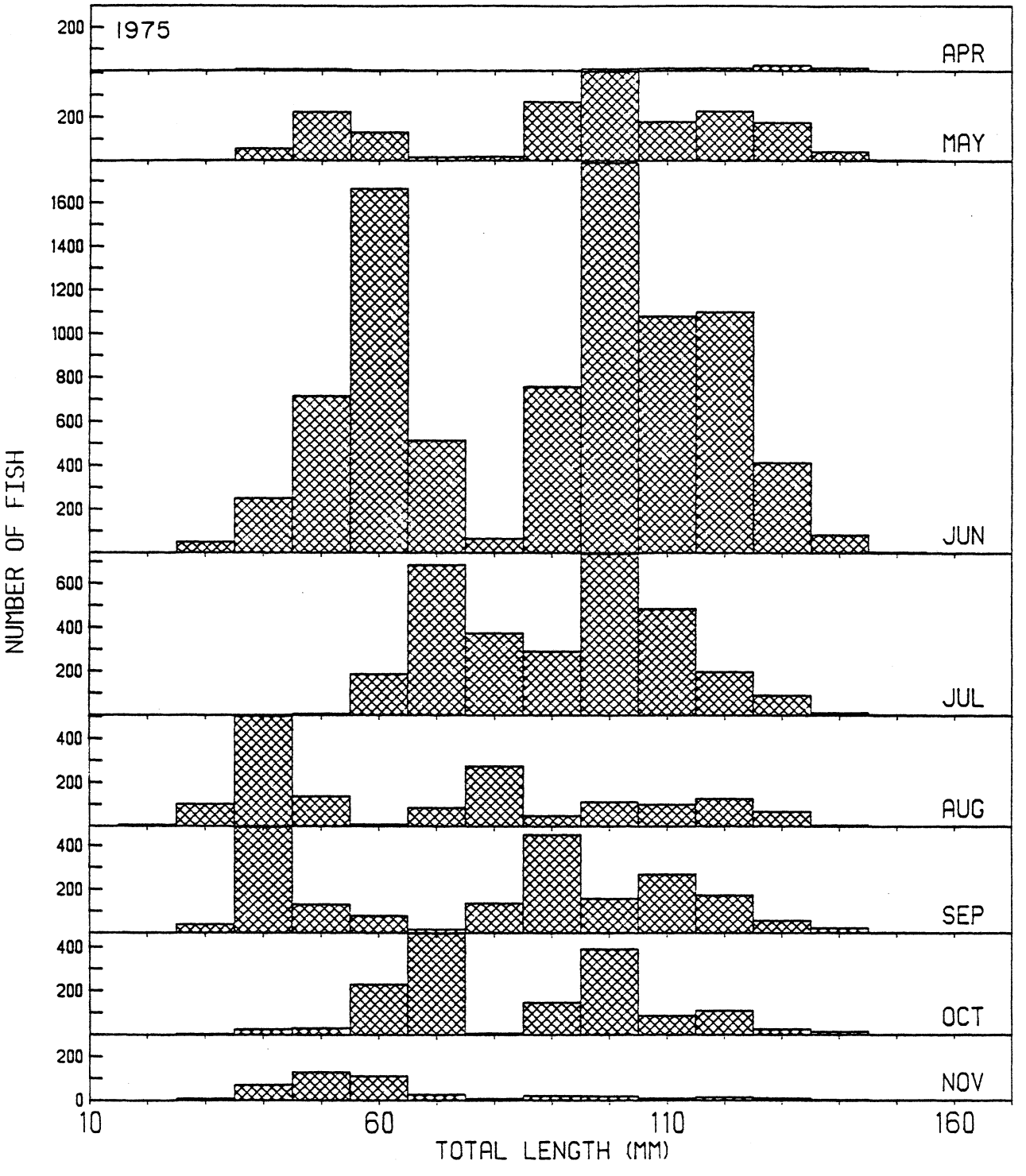
Appendix 43. Length-frequency histograms of alewives caught during 1977 field sampling at the Cook Plant, southeastern Lake Michigan.



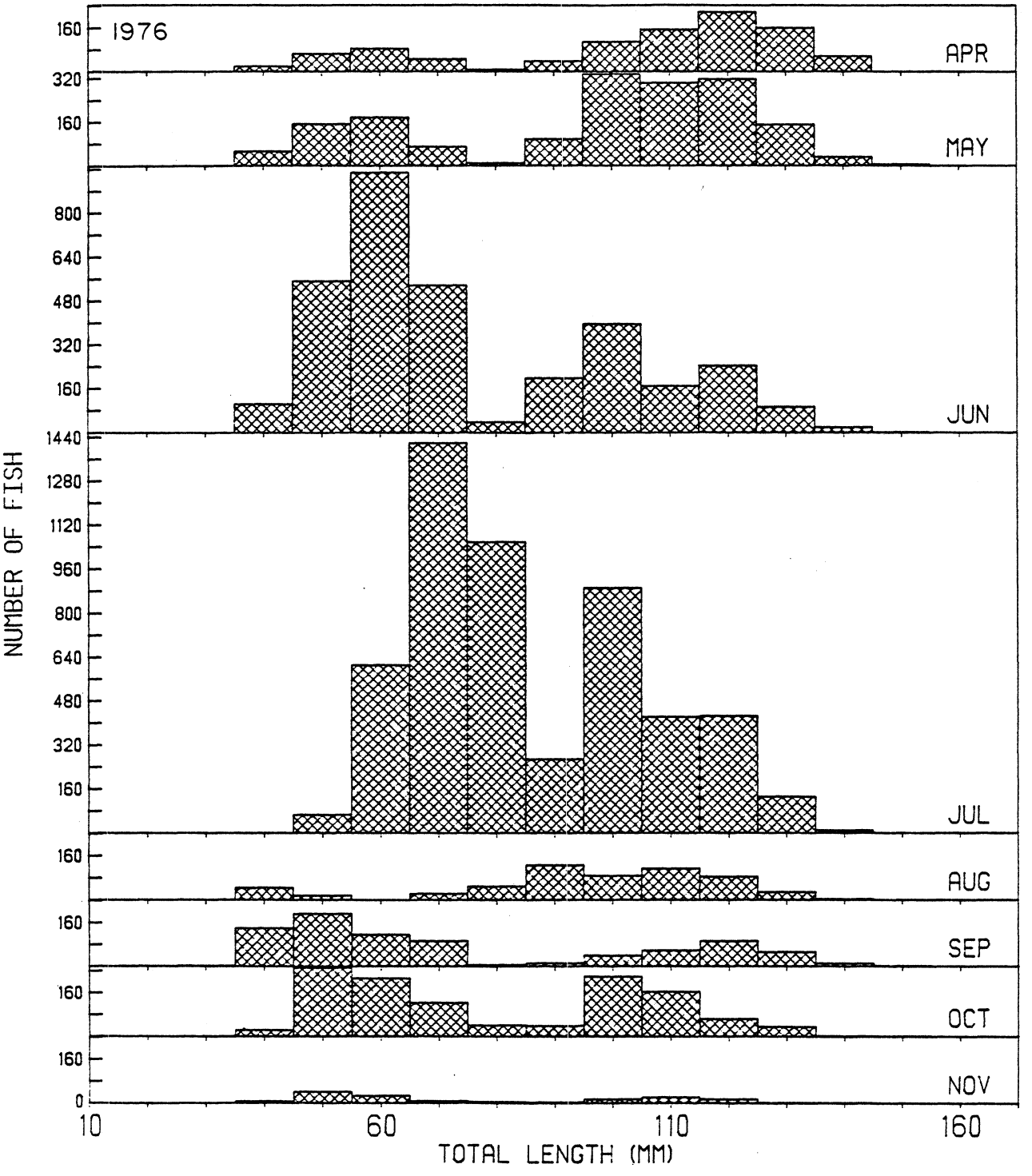
Appendix 44. Length-frequency histograms of alewives caught during 1978 field sampling at the Cook Plant, southeastern Lake Michigan.



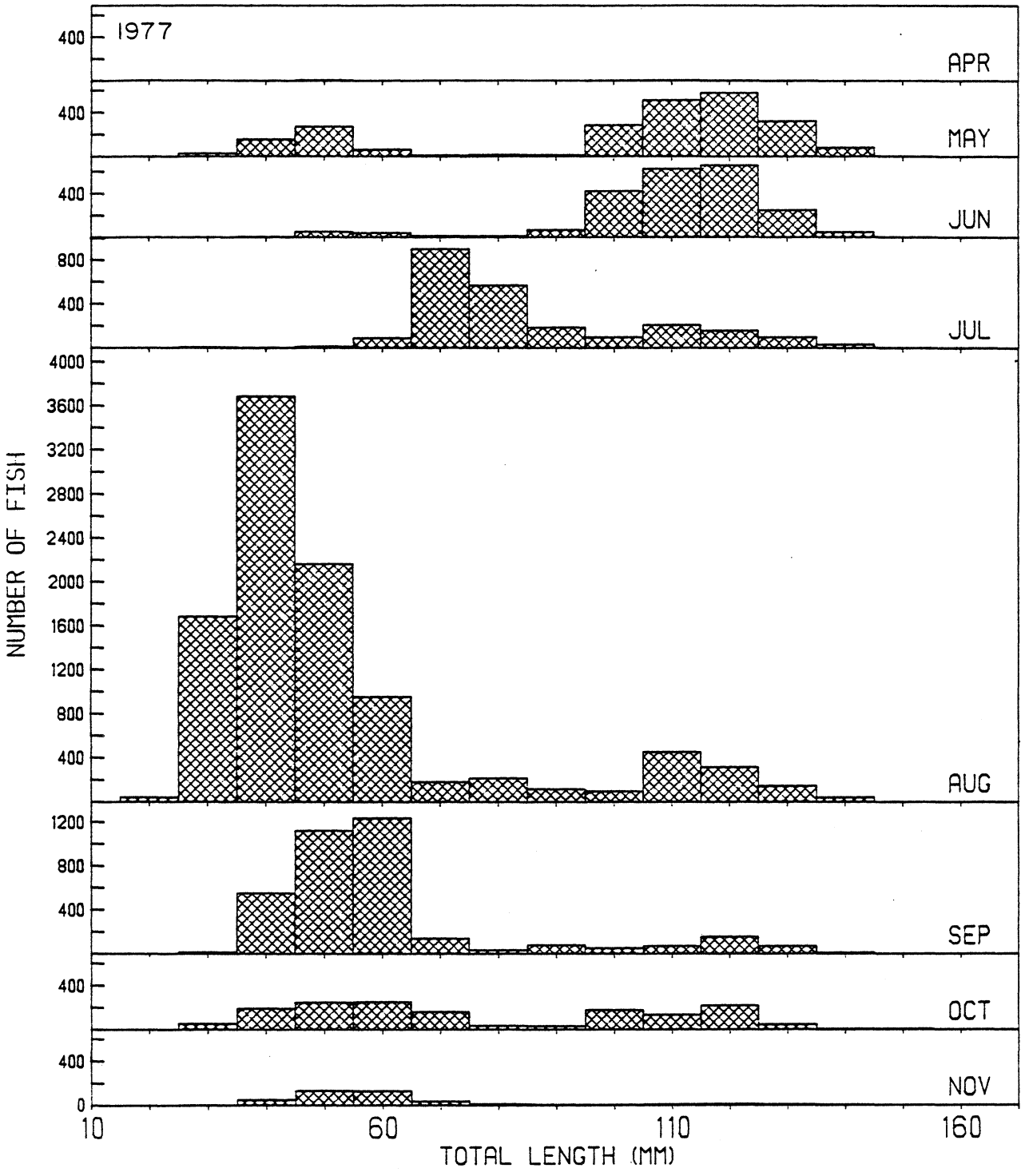
Appendix 45. Length-frequency histograms of alewives caught during 1979 field sampling at the Cook Plant, southeastern Lake Michigan.



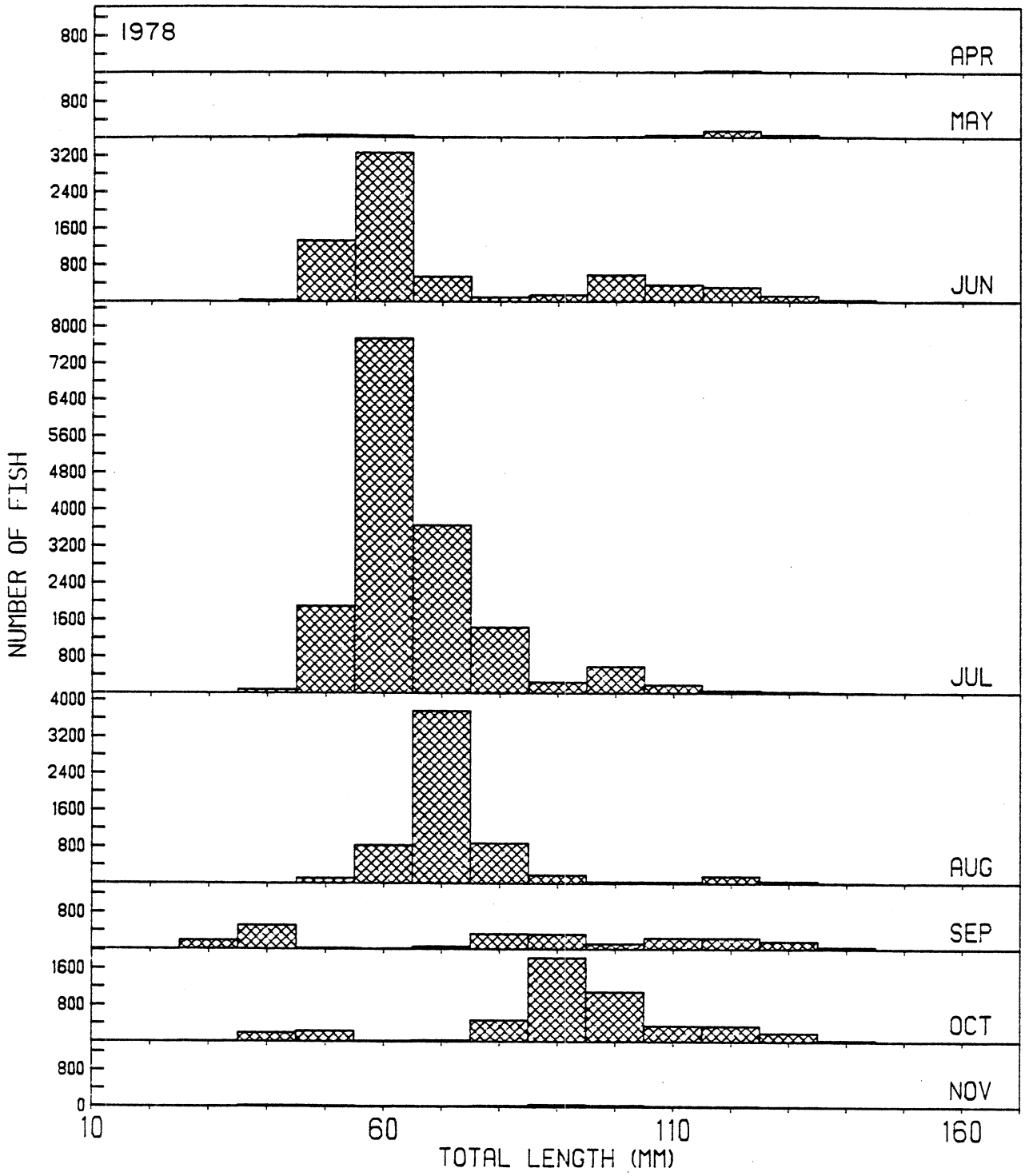
Appendix 46. Length-frequency histograms of spottail shiners caught during 1975 field sampling at the Cook Plant, southeastern Lake Michigan.



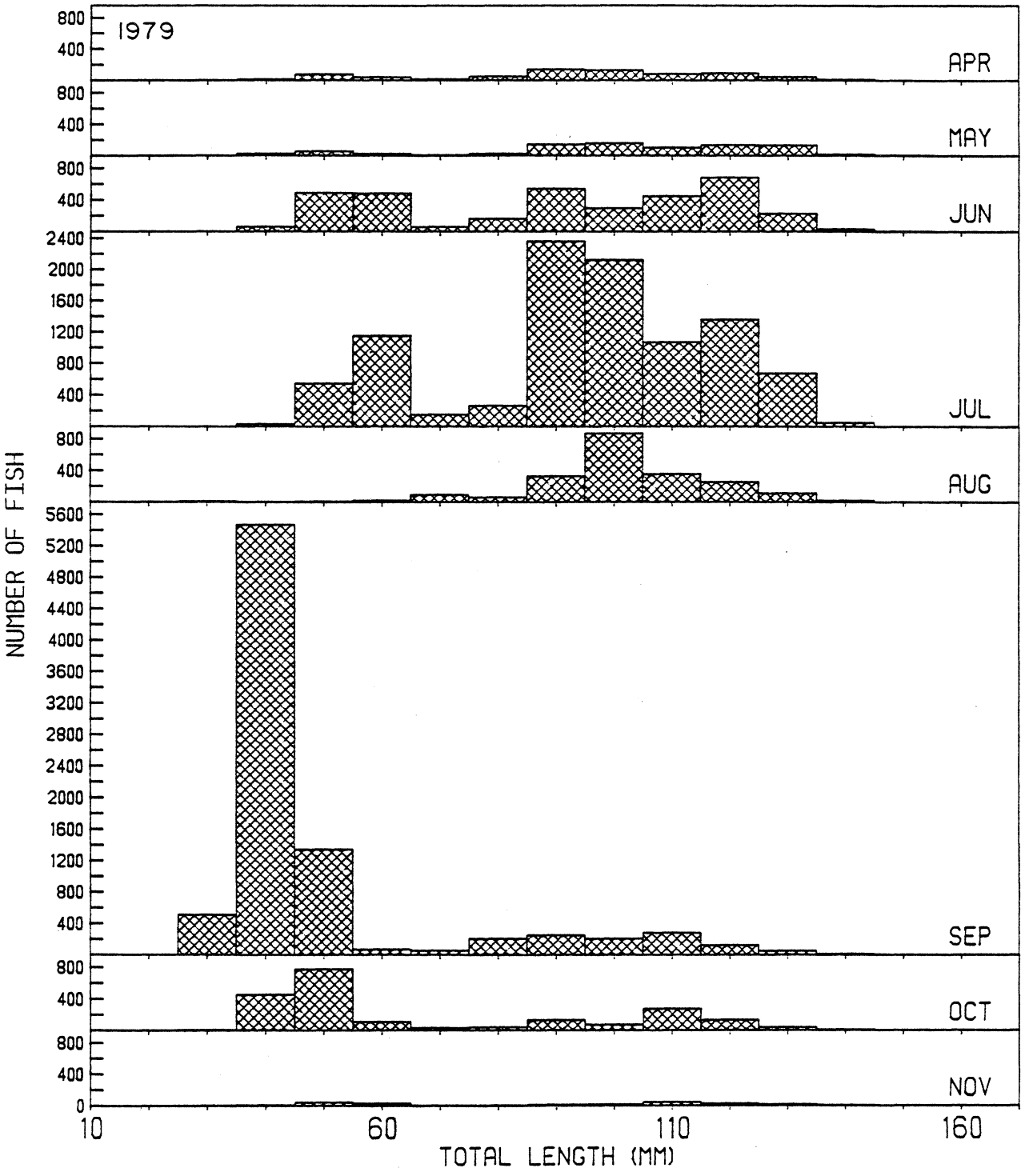
Appendix 47. Length-frequency histograms of spottail shiners caught during 1976 field sampling at the Cook Plant, southeastern Lake Michigan.



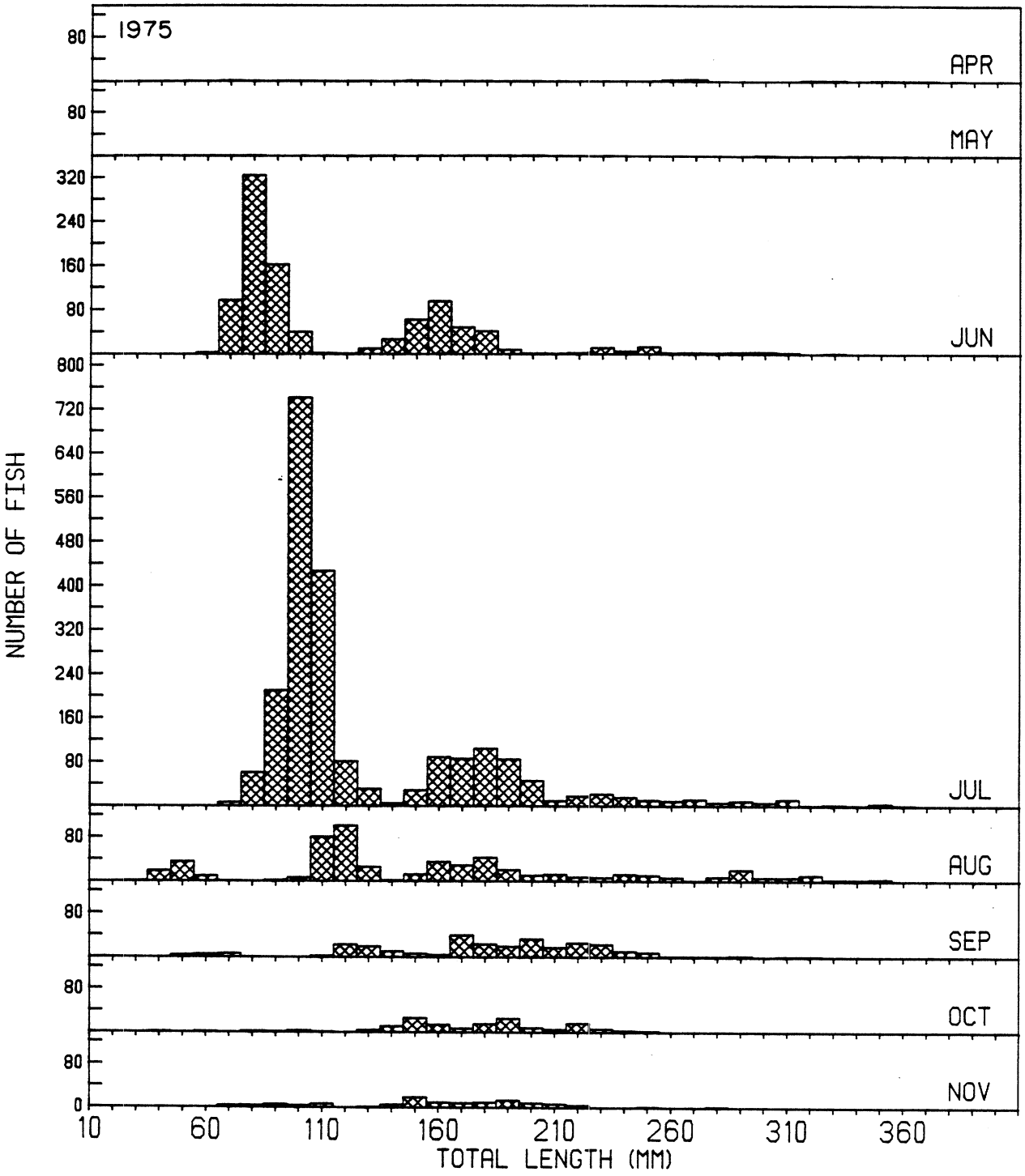
Appendix 48. Length-frequency histograms of spottail shiners caught during 1977 field sampling at the Cook Plant, southeastern Lake Michigan.



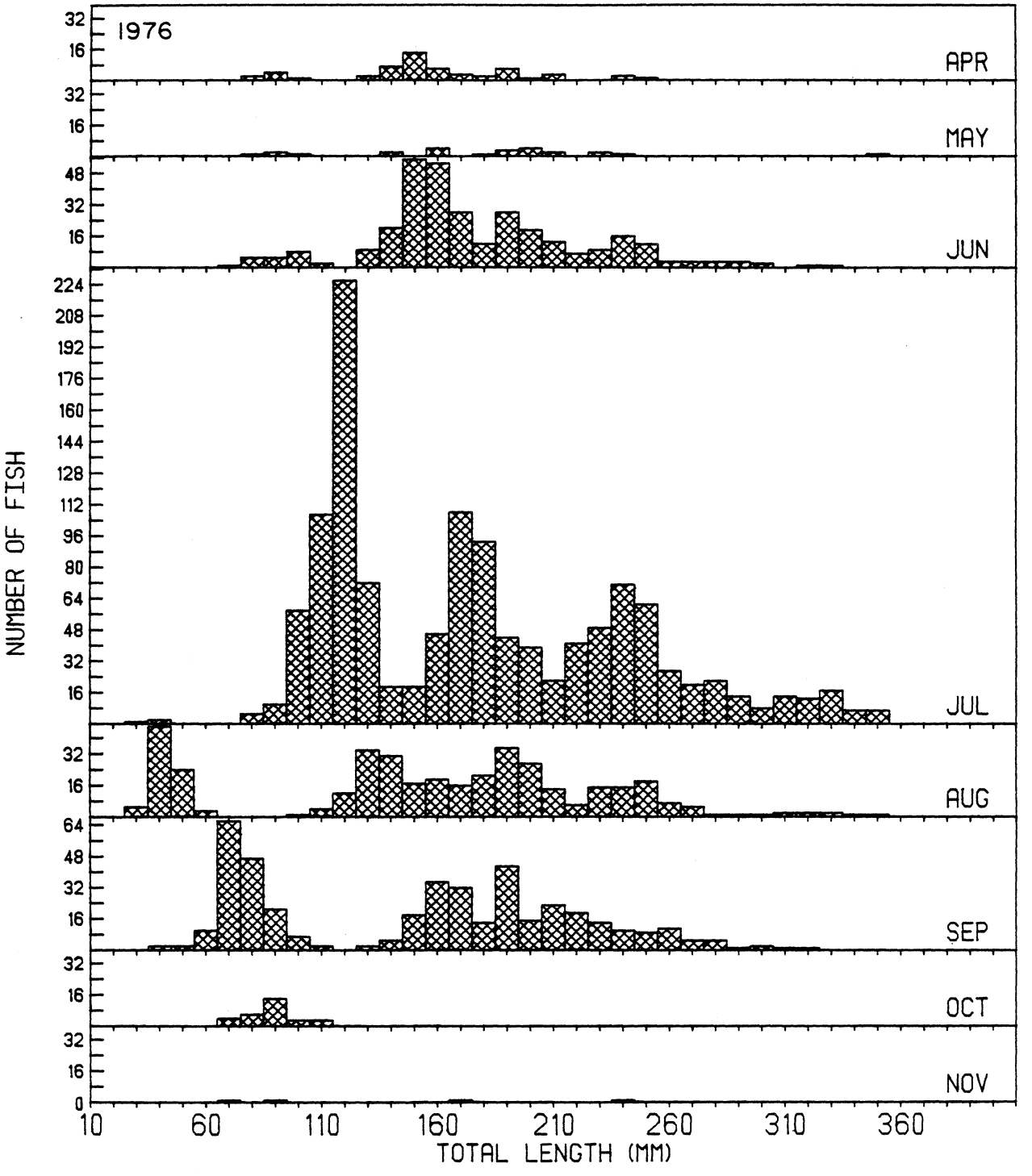
Appendix 49. Length-frequency histograms of spottail shiners caught during 1978 field sampling at the Cook Plant, southeastern Lake Michigan.



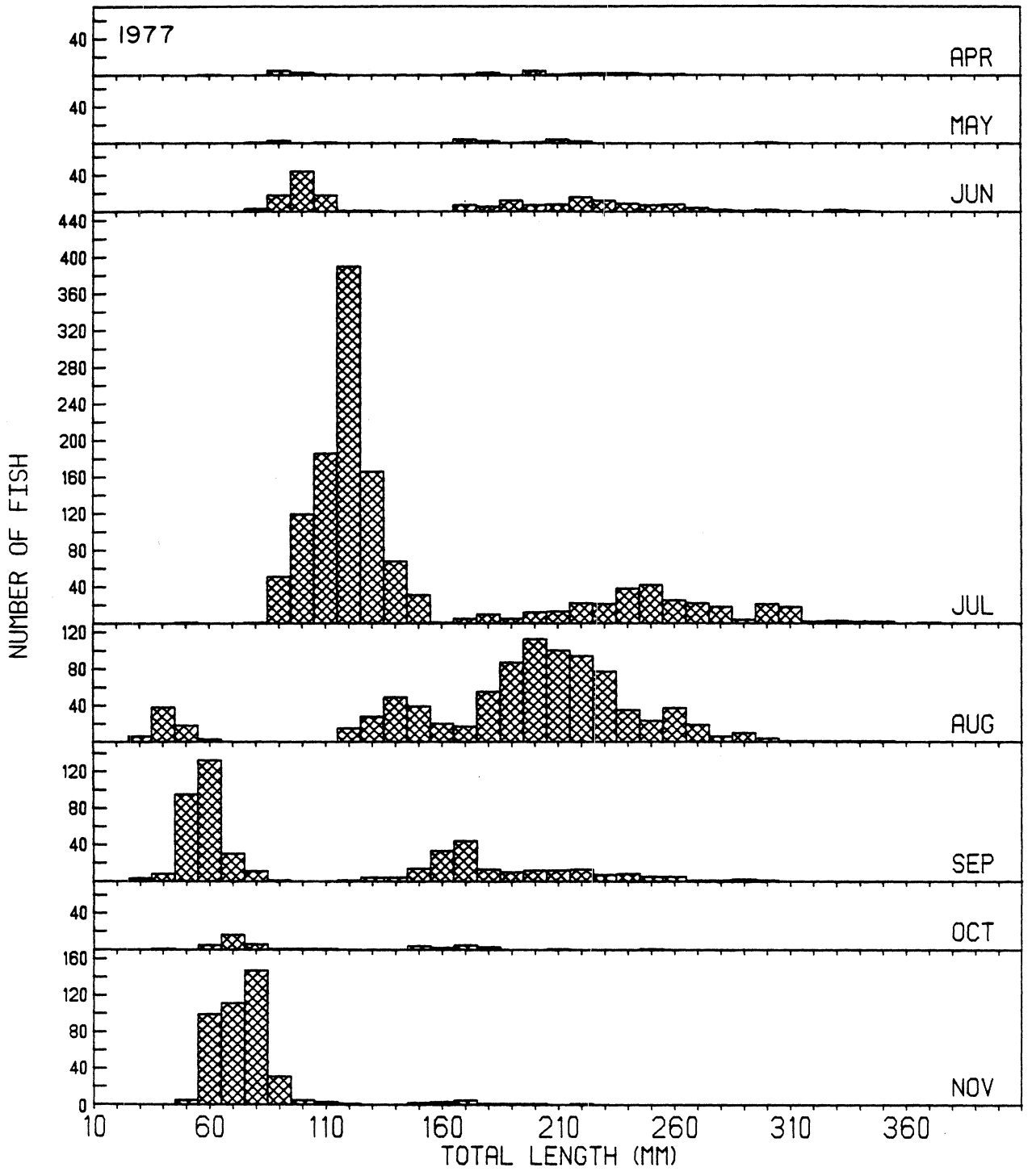
Appendix 50. Length-frequency histograms of spottail shiners caught during 1979 field sampling at the Cook Plant, southeastern Lake Michigan.



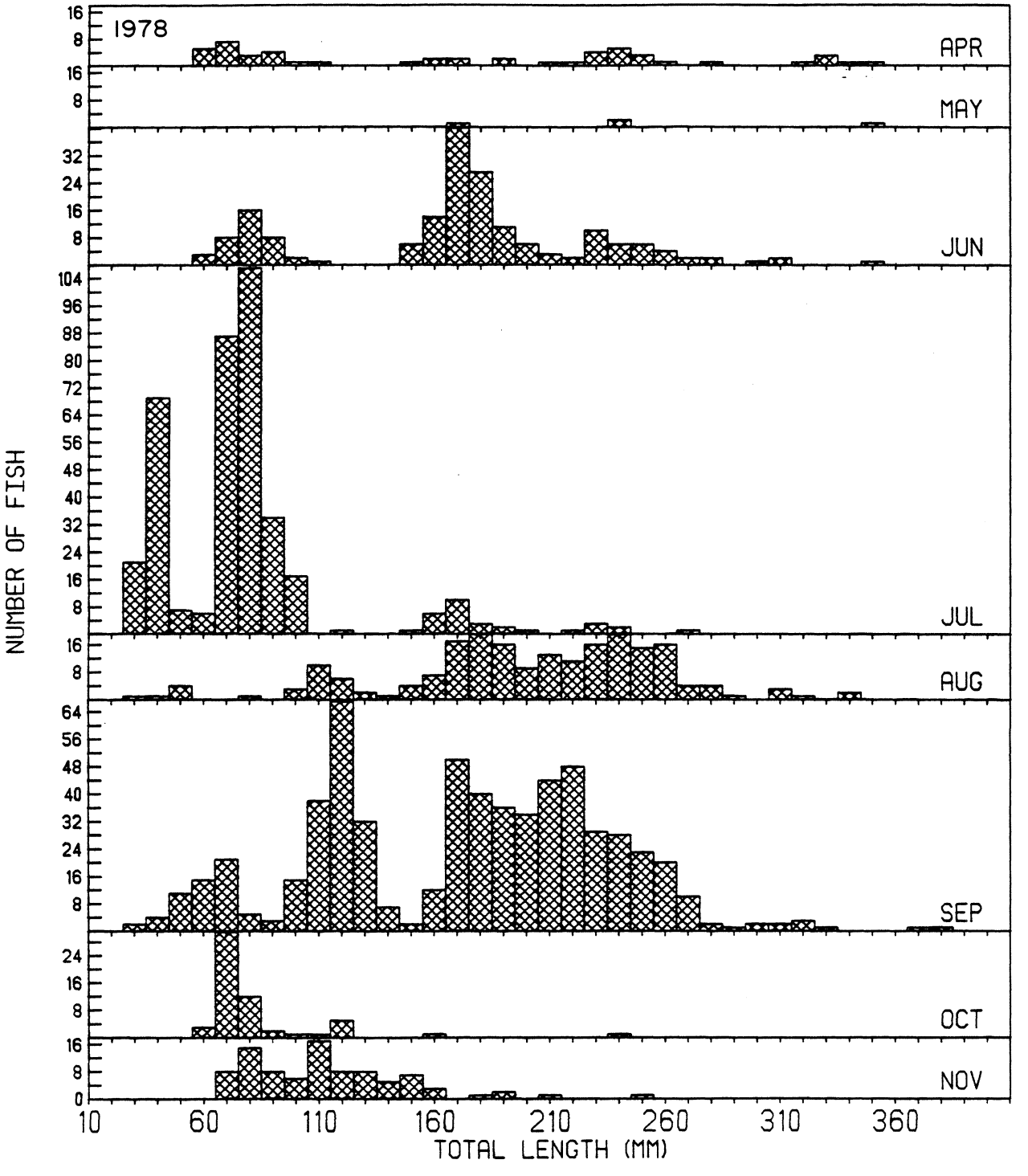
Appendix 51. Length-frequency histograms of yellow perch caught during 1975 field sampling at the Cook Plant, southeastern Lake Michigan.



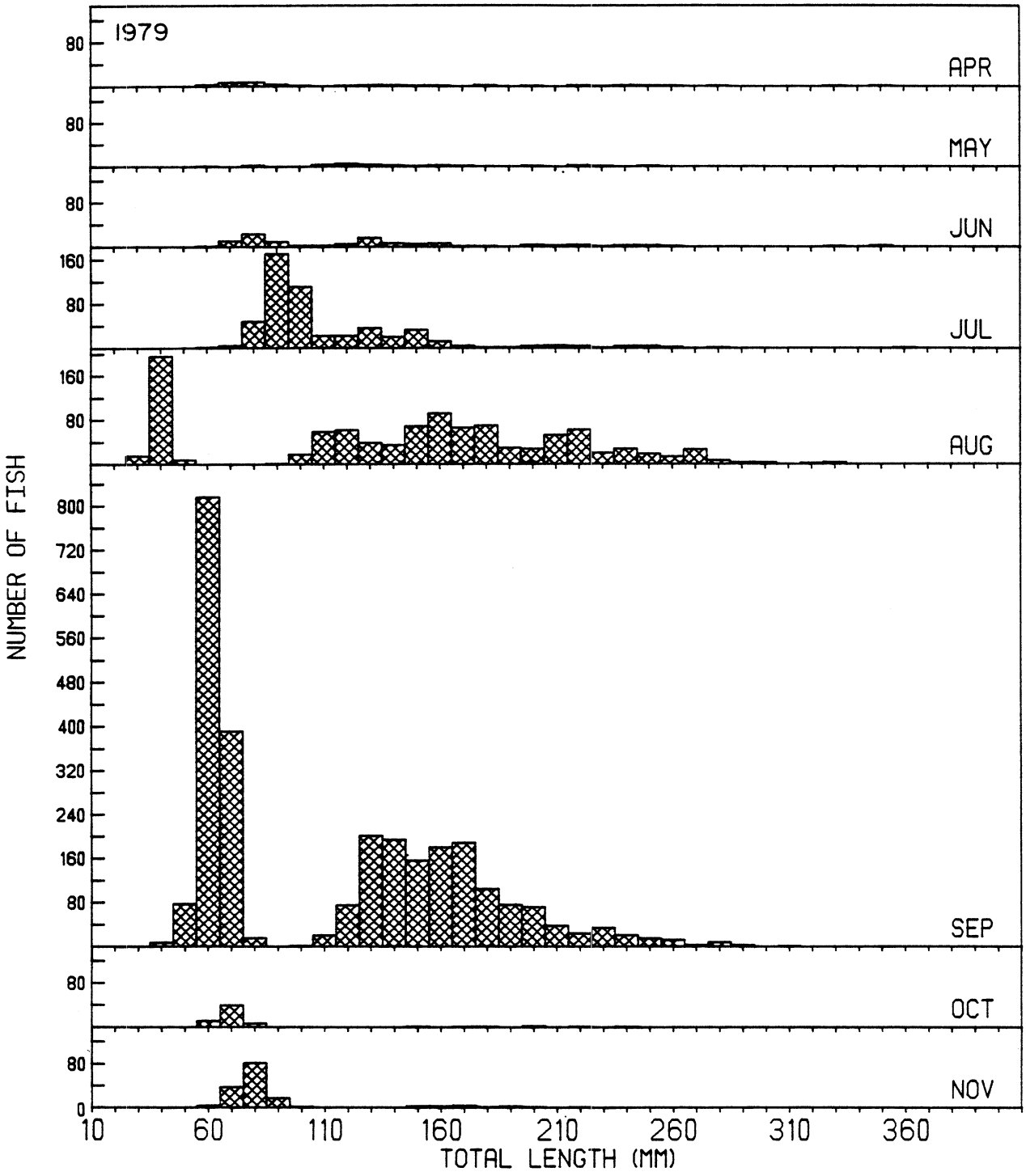
Appendix 52. Length-frequency histograms of yellow perch caught during 1976 field sampling at the Cook Plant, southeastern Lake Michigan.



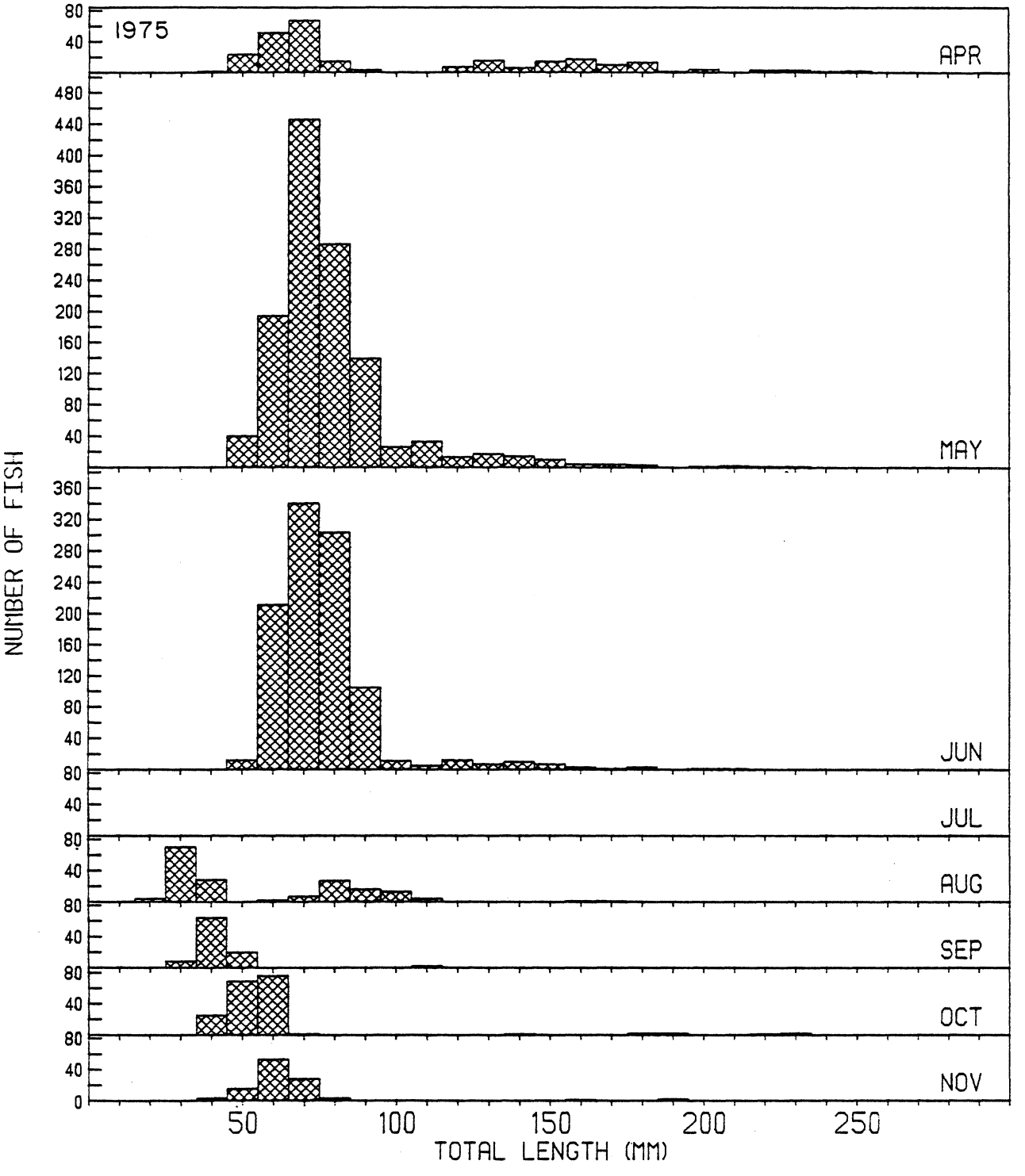
Appendix 53. Length-frequency histograms of yellow perch caught during 1977 field sampling at the Cook Plant, southeastern Lake Michigan.



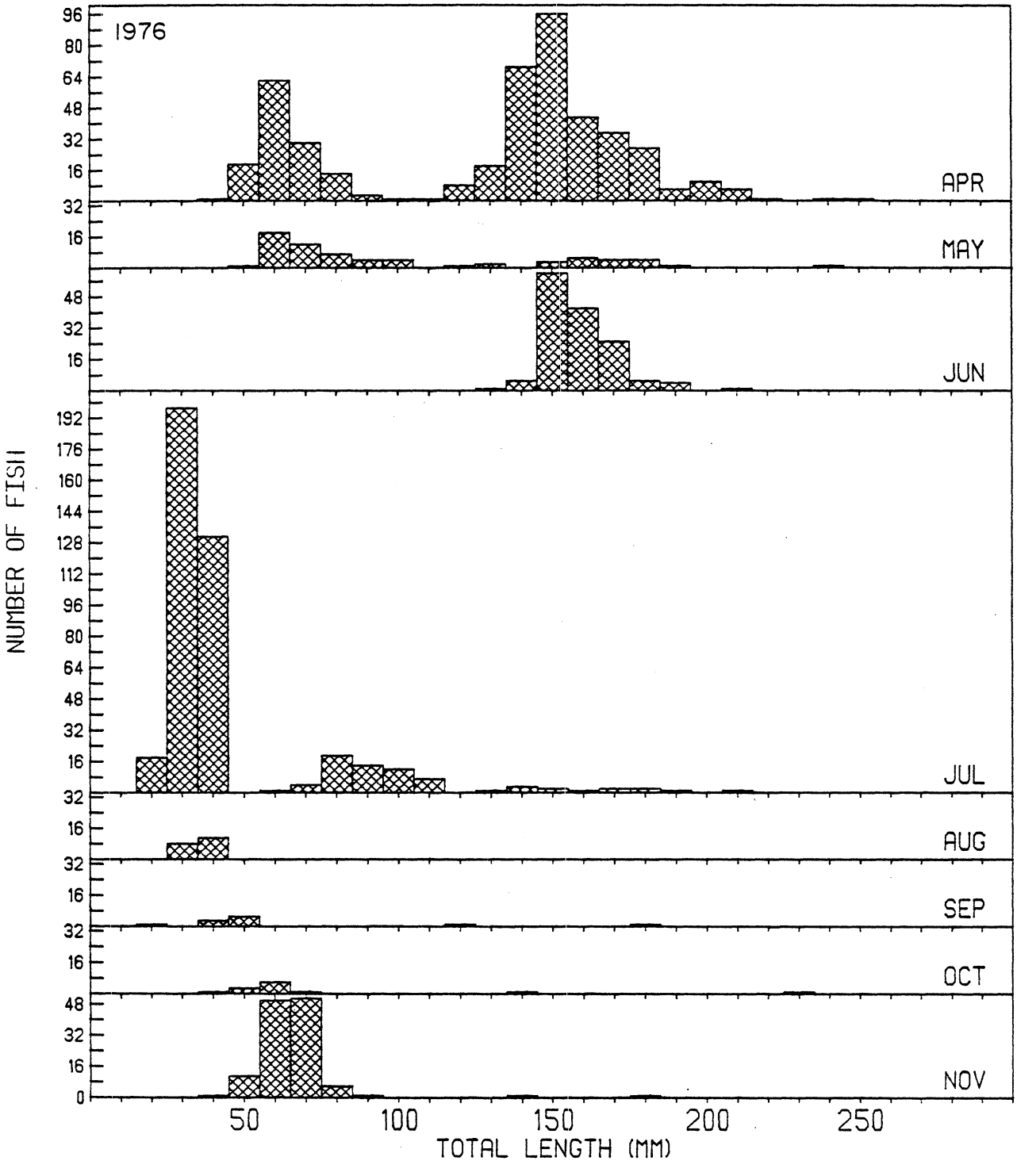
Appendix 54. Length-frequency histograms of yellow perch caught during 1978 field sampling at the Cook Plant, southeastern Lake Michigan.



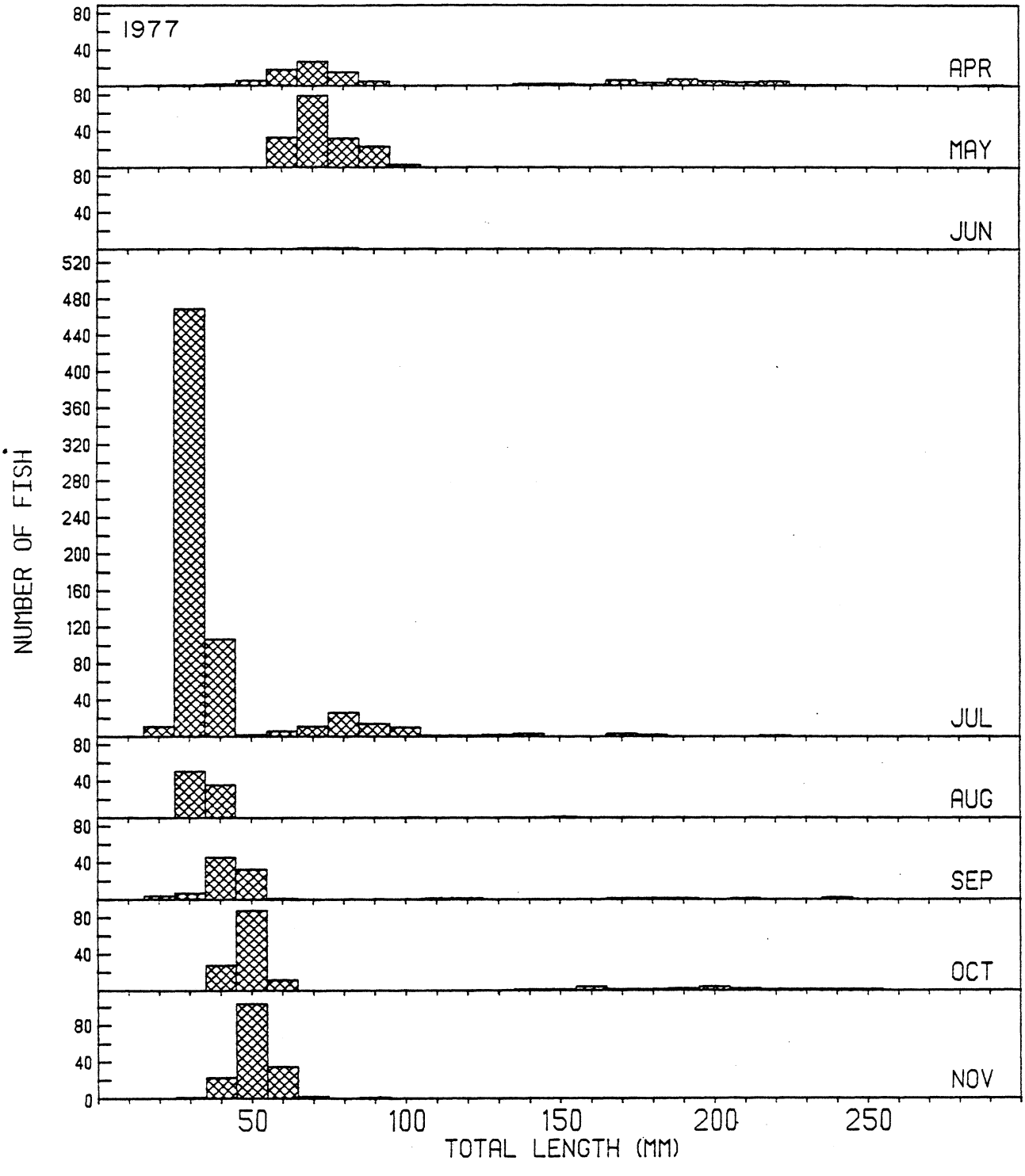
Appendix 55. Length-frequency histograms of yellow perch caught during 1979 field sampling at the Cook Plant, southeastern Lake Michigan.



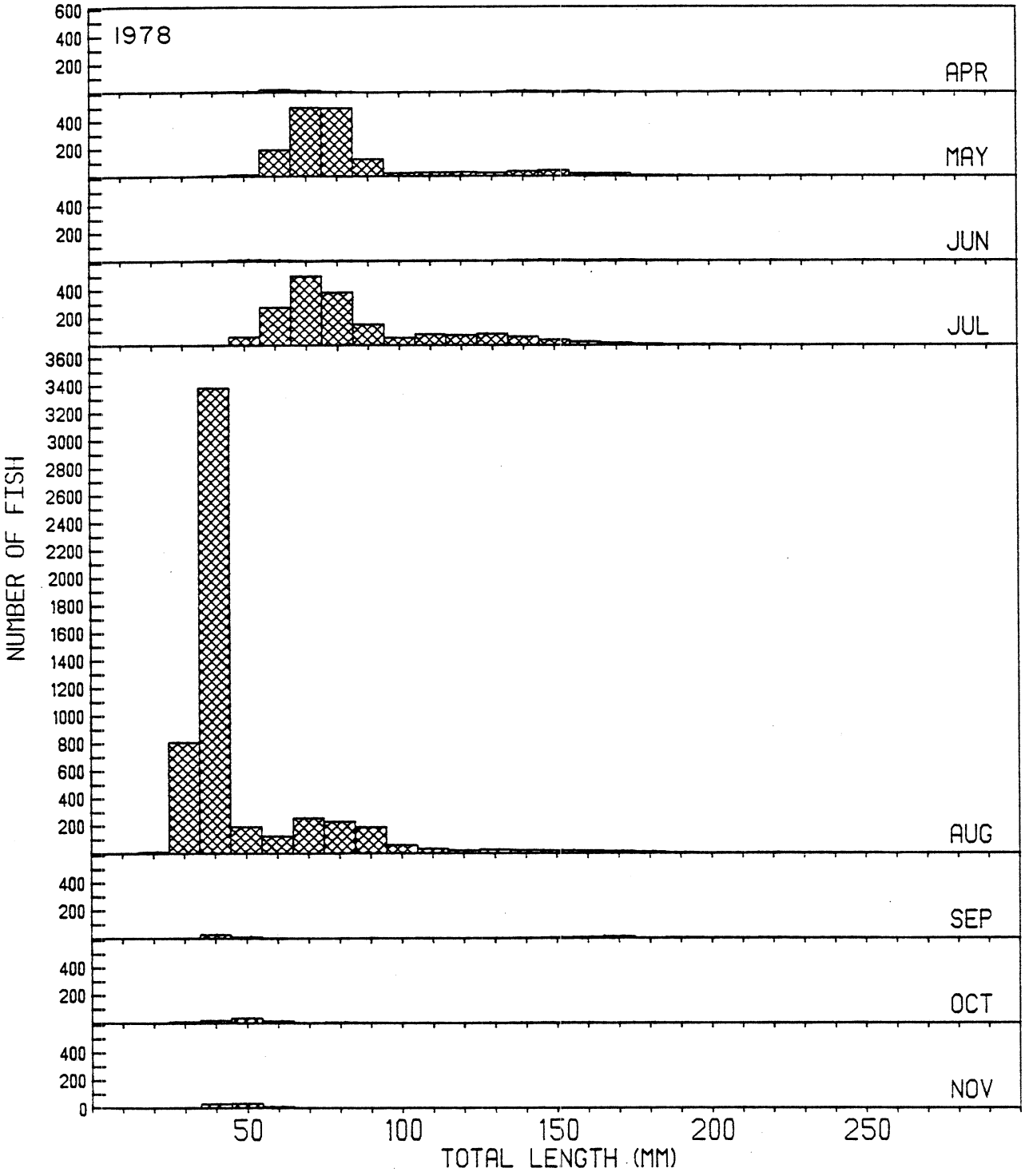
Appendix 56. Length-frequency histograms of rainbow smelt caught during 1975 field sampling at the Cook Plant, southeastern Lake Michigan.



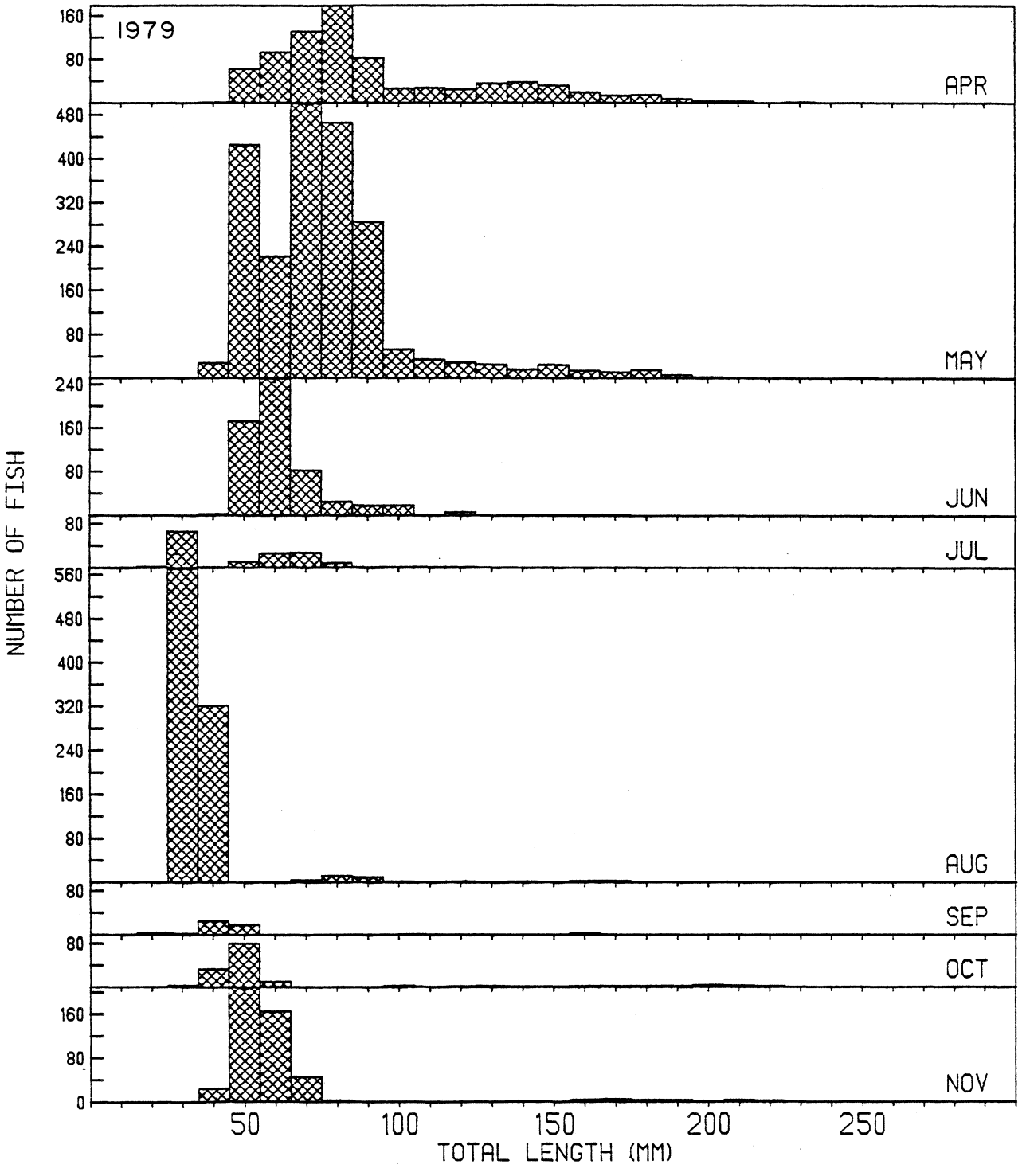
Appendix 57. Length-frequency histograms of rainbow smelt caught during 1976 field sampling at the Cook Plant, southeastern Lake Michigan.



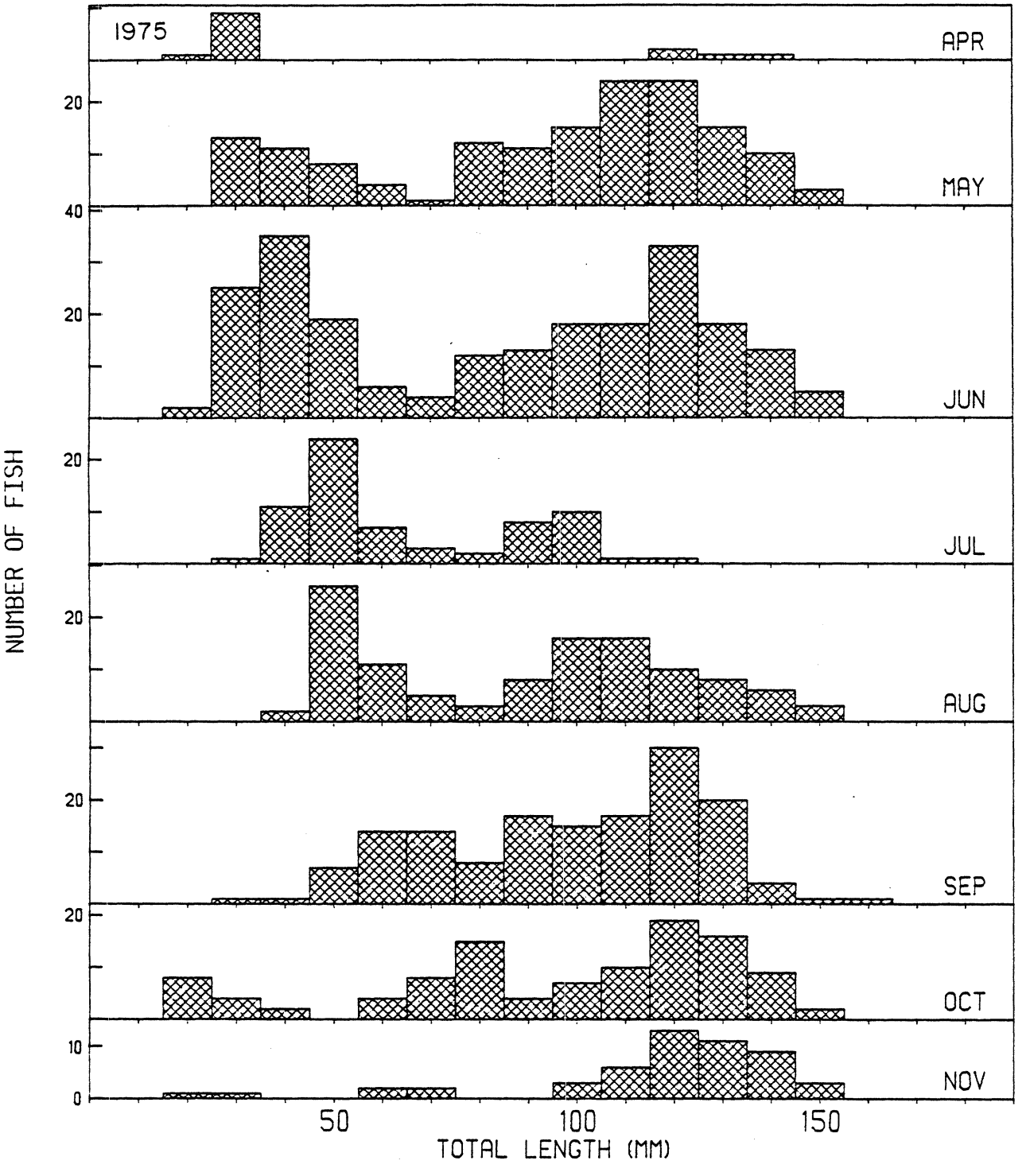
Appendix 58. Length-frequency histograms of rainbow smelt caught during 1977 field sampling at the Cook Plant, southeastern Lake Michigan.



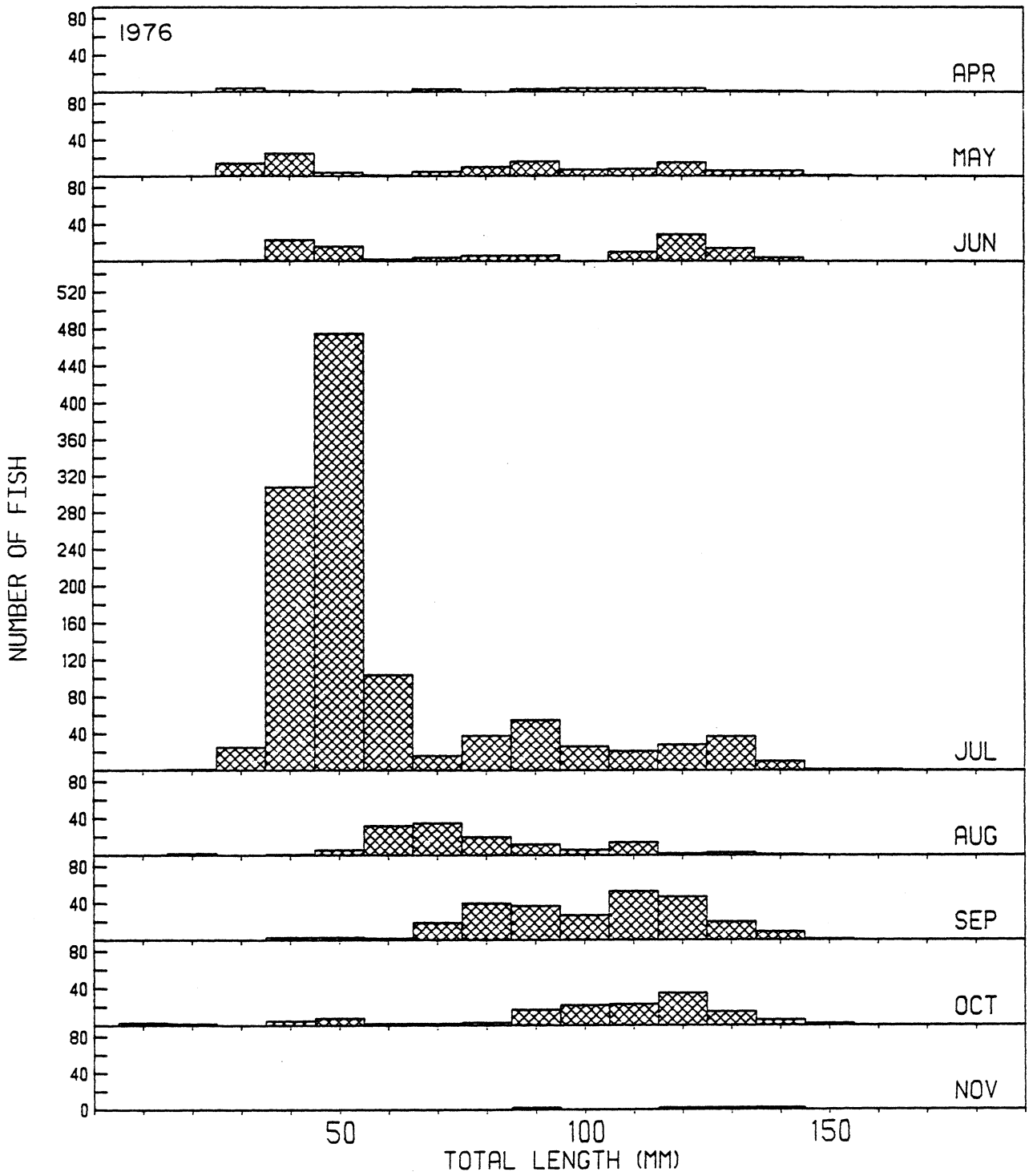
Appendix 59. Length-frequency histograms of rainbow smelt caught during 1978 field sampling at the Cook Plant, southeastern Lake Michigan.



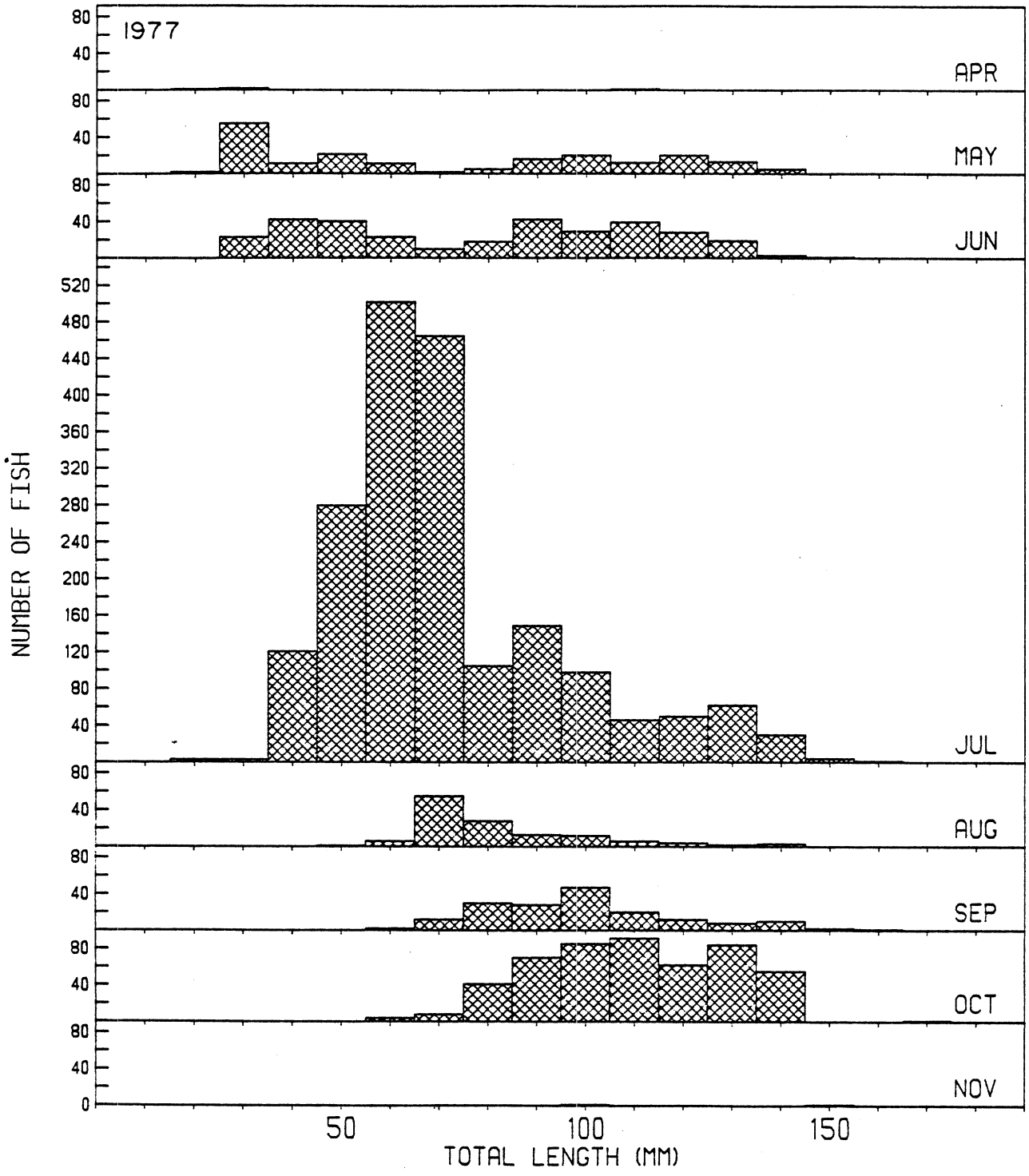
Appendix 60. Length-frequency histograms of rainbow smelt caught during 1979 field sampling at the Cook Plant, southeastern Lake Michigan.



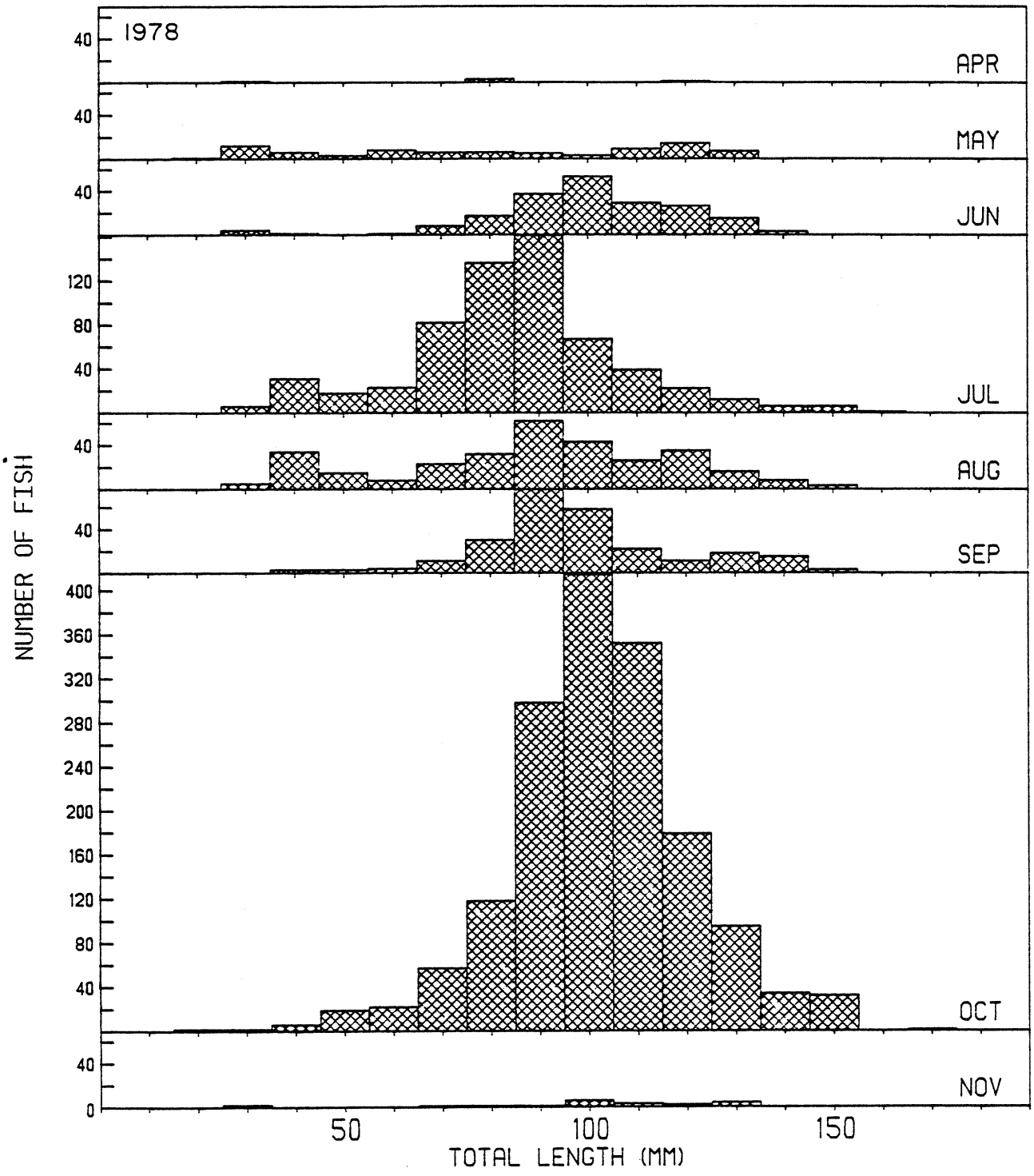
Appendix 61. Length-frequency histograms of trout-perch caught during 1975 field sampling at the Cook Plant, southeastern Lake Michigan.



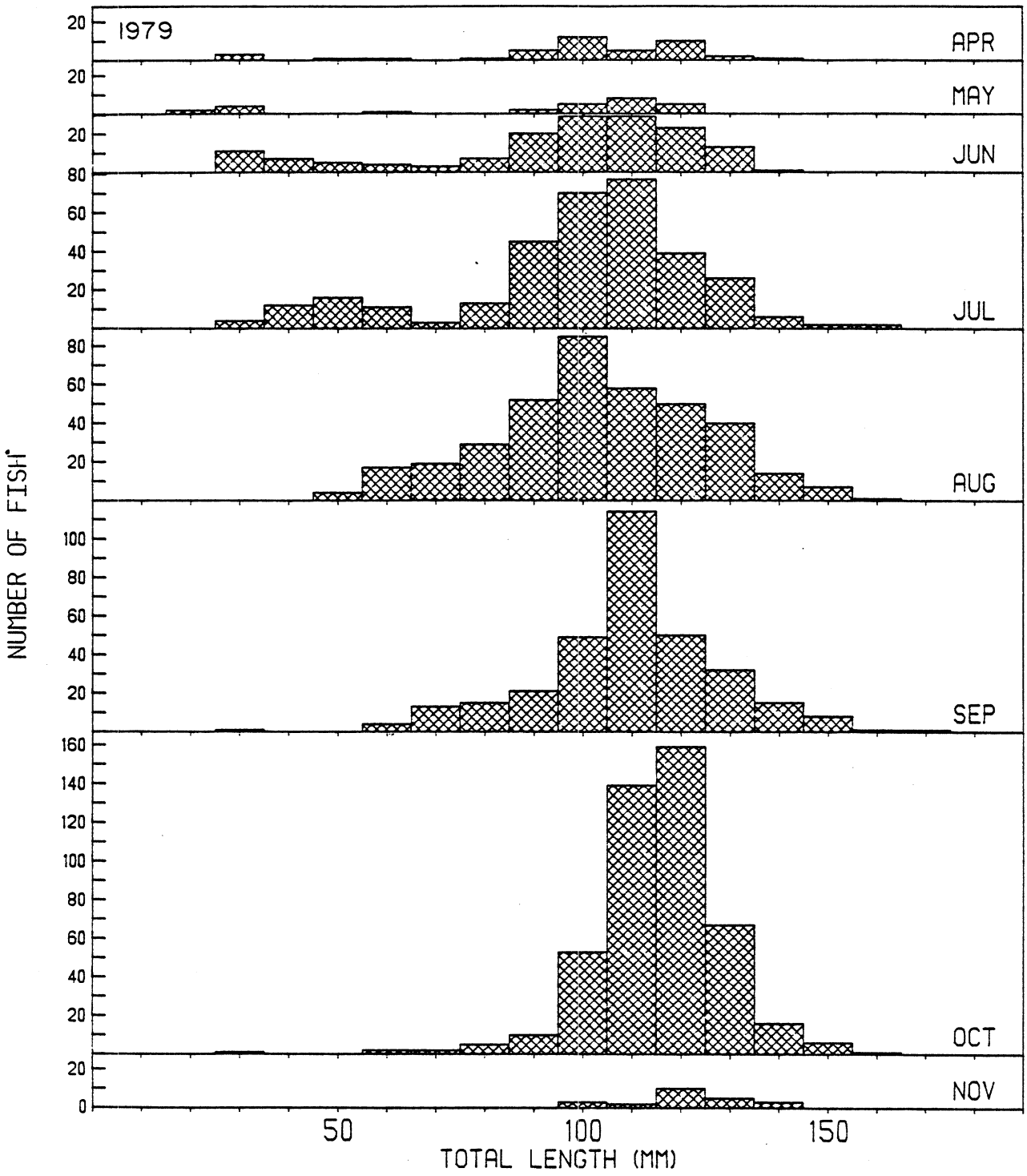
Appendix 62. Length-frequency histograms of trout-perch caught during 1976 field sampling at the Cook Plant, southeastern Lake Michigan.



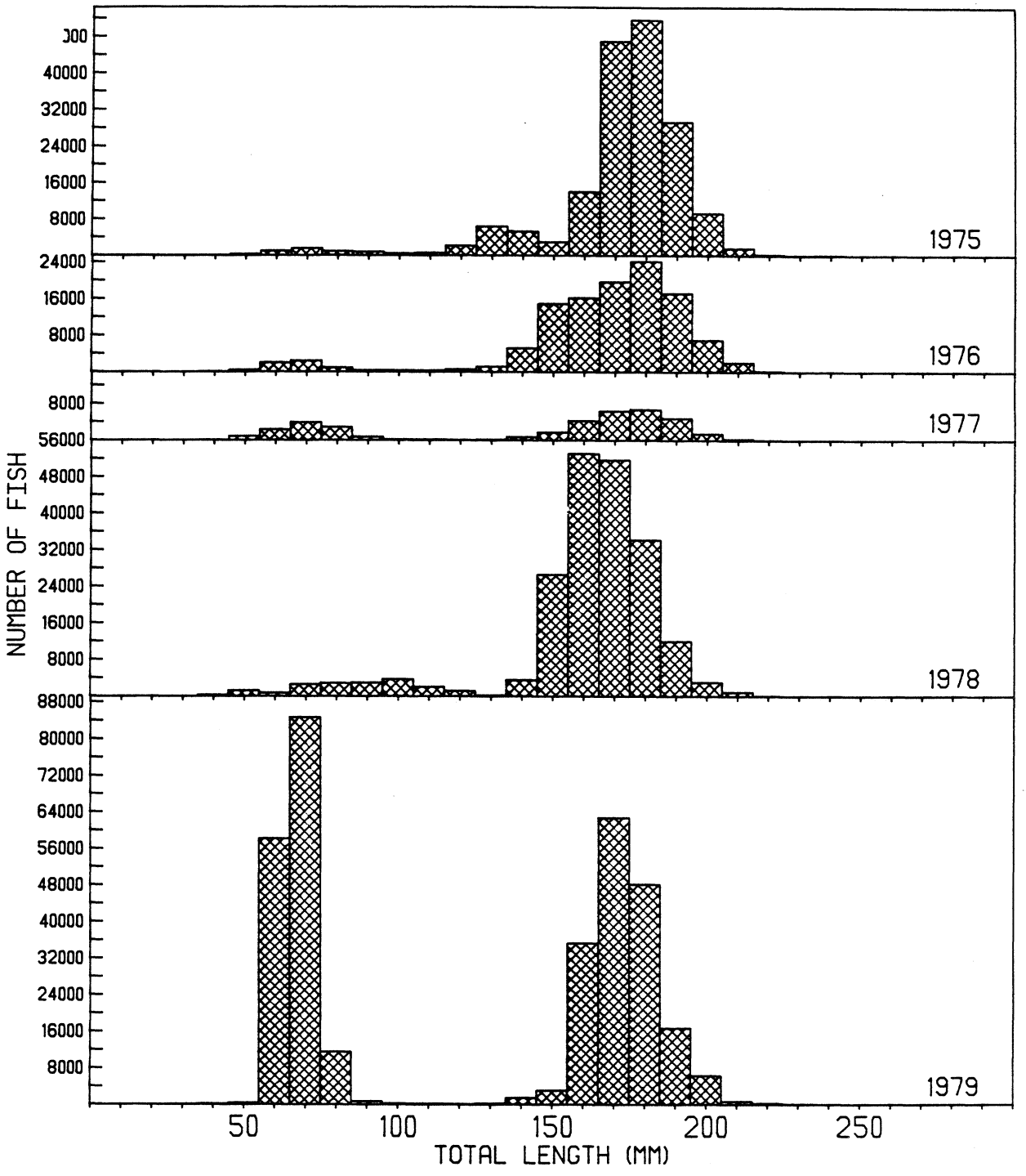
Appendix 63. Length-frequency histograms of trout-perch caught during 1977 field sampling at the Cook Plant, southeastern Lake Michigan.



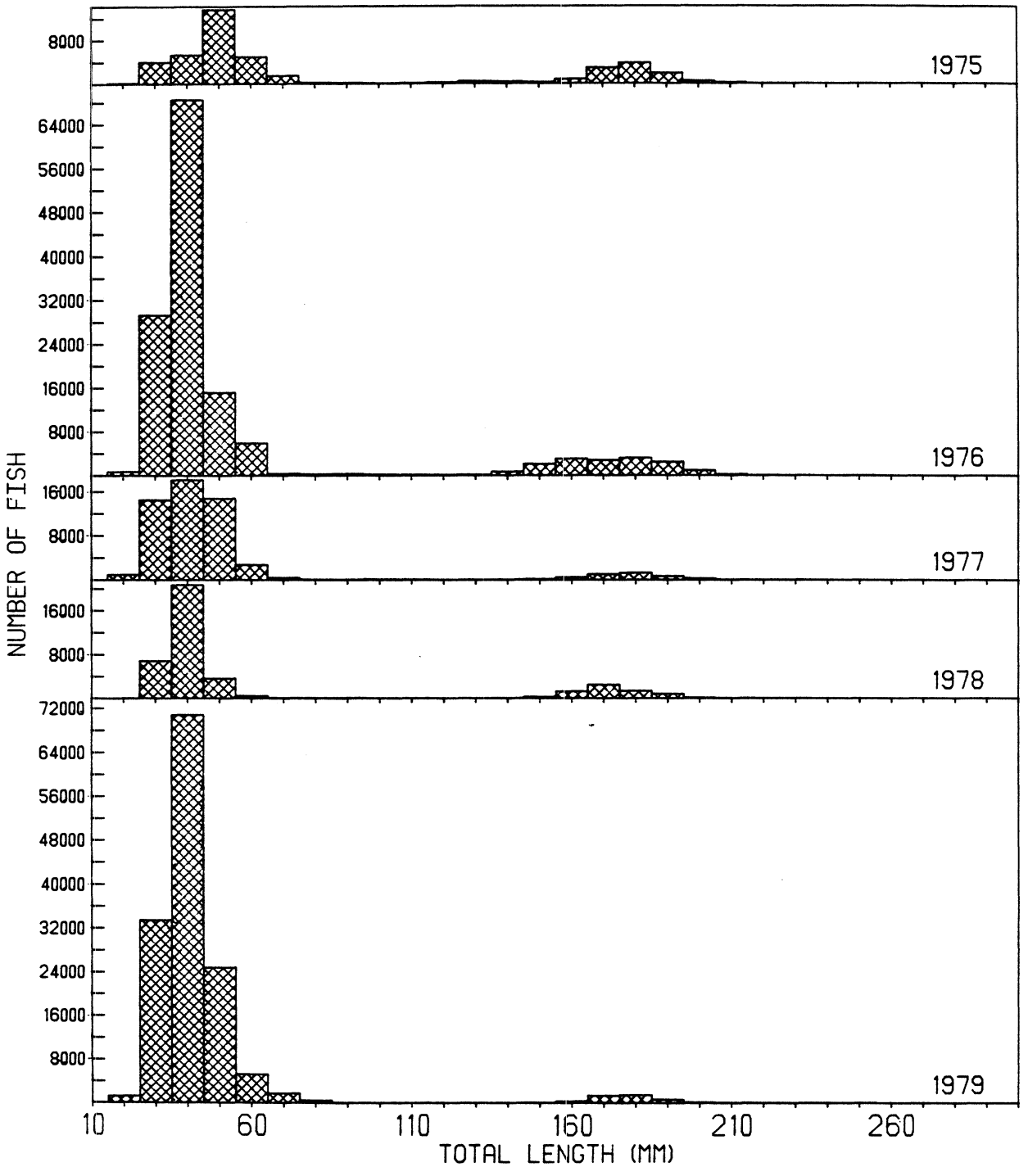
Appendix 64. Length-frequency histograms of trout-perch caught during 1978 field sampling at the Cook Plant, southeastern Lake Michigan.



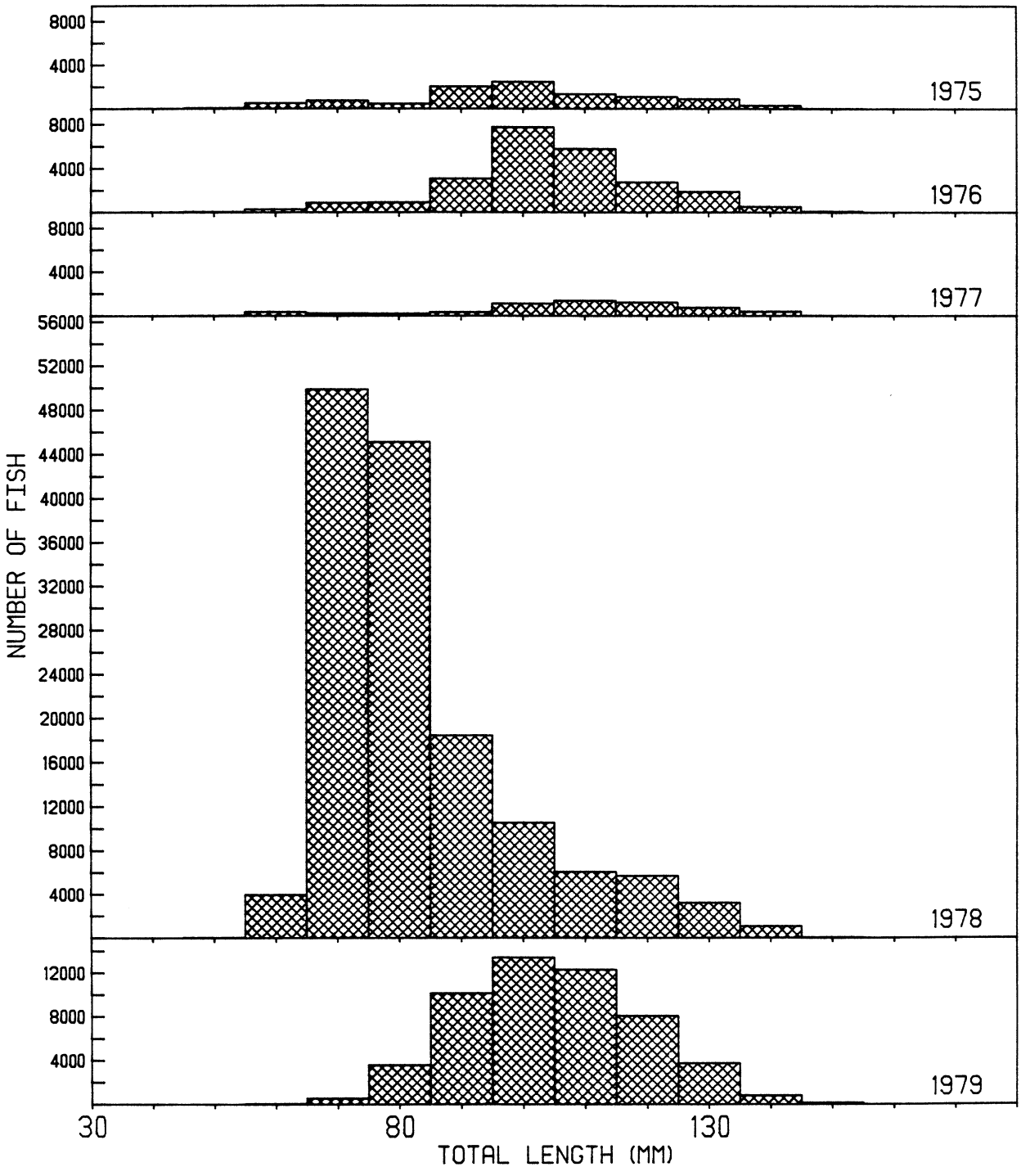
Appendix 65. Length-frequency histograms of trout-perch caught during 1979 field sampling at the Cook Plant, southeastern Lake Michigan.



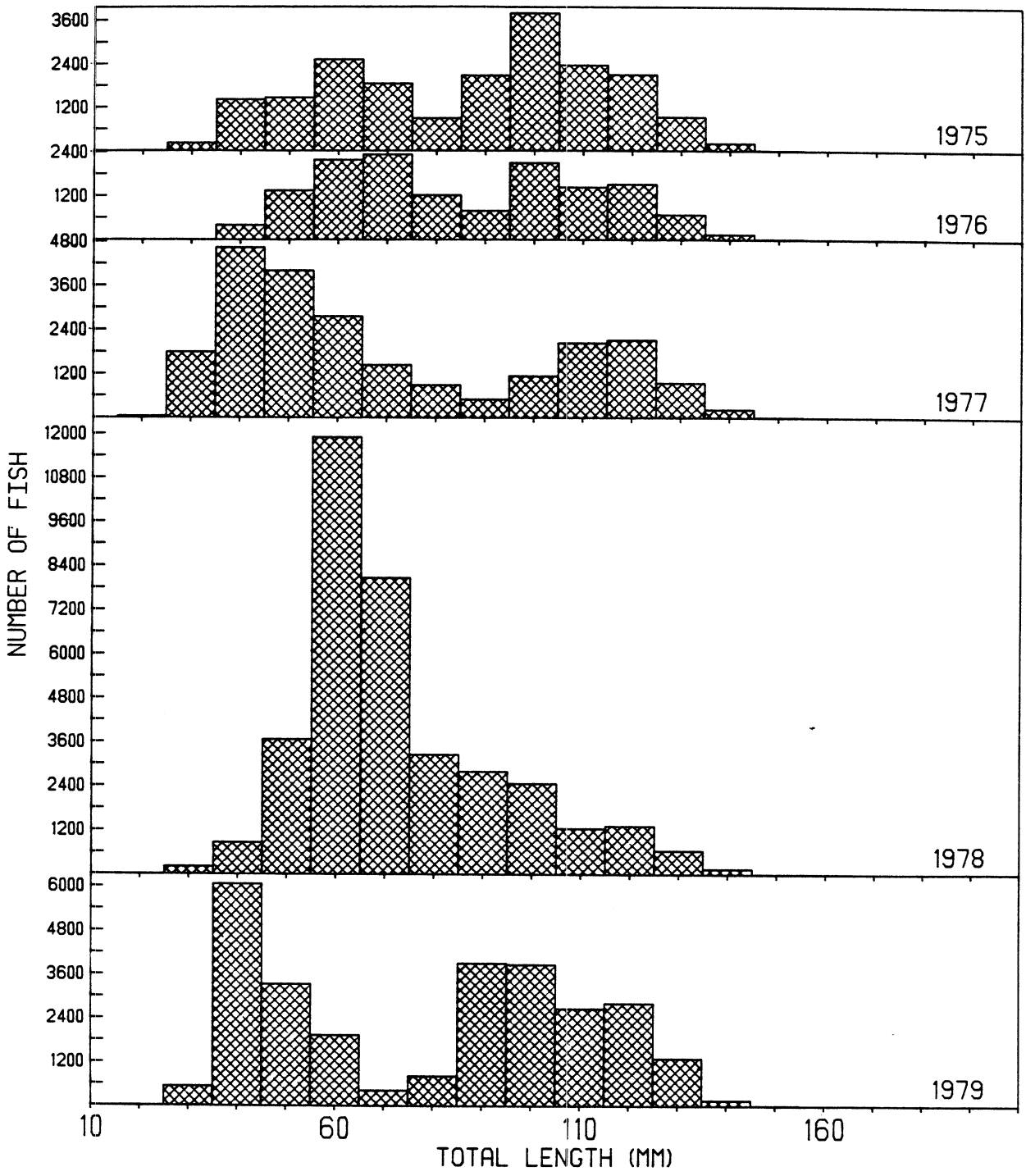
Appendix 66. Length-frequency histograms of alewives impinged from 1975 through 1979 at the Cook Plant, southeastern Lake Michigan.



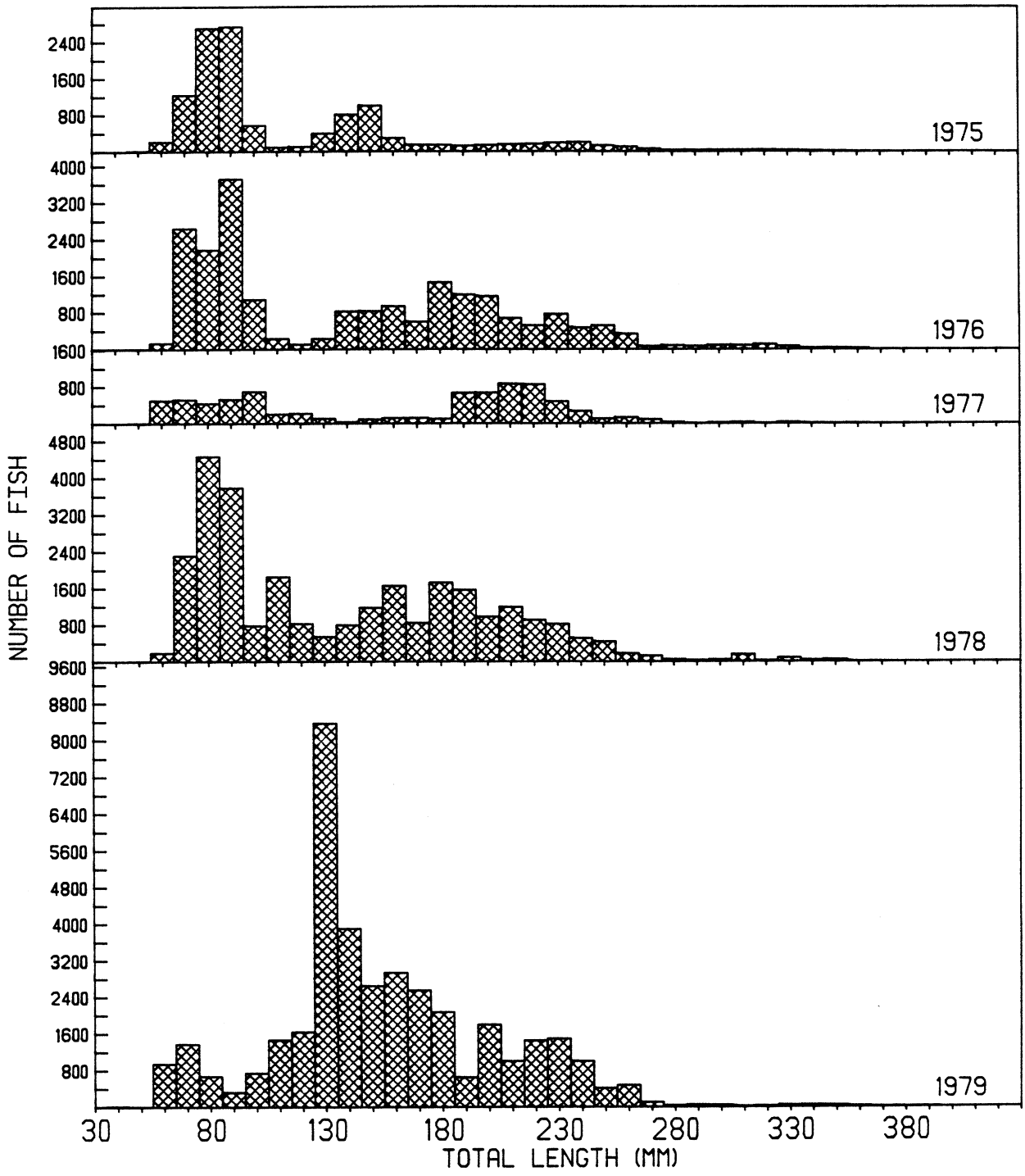
Appendix 67. Length-frequency histograms of alewives caught during field-sampling from 1975-1979 at the Cook Plant, southeastern Lake Michigan.



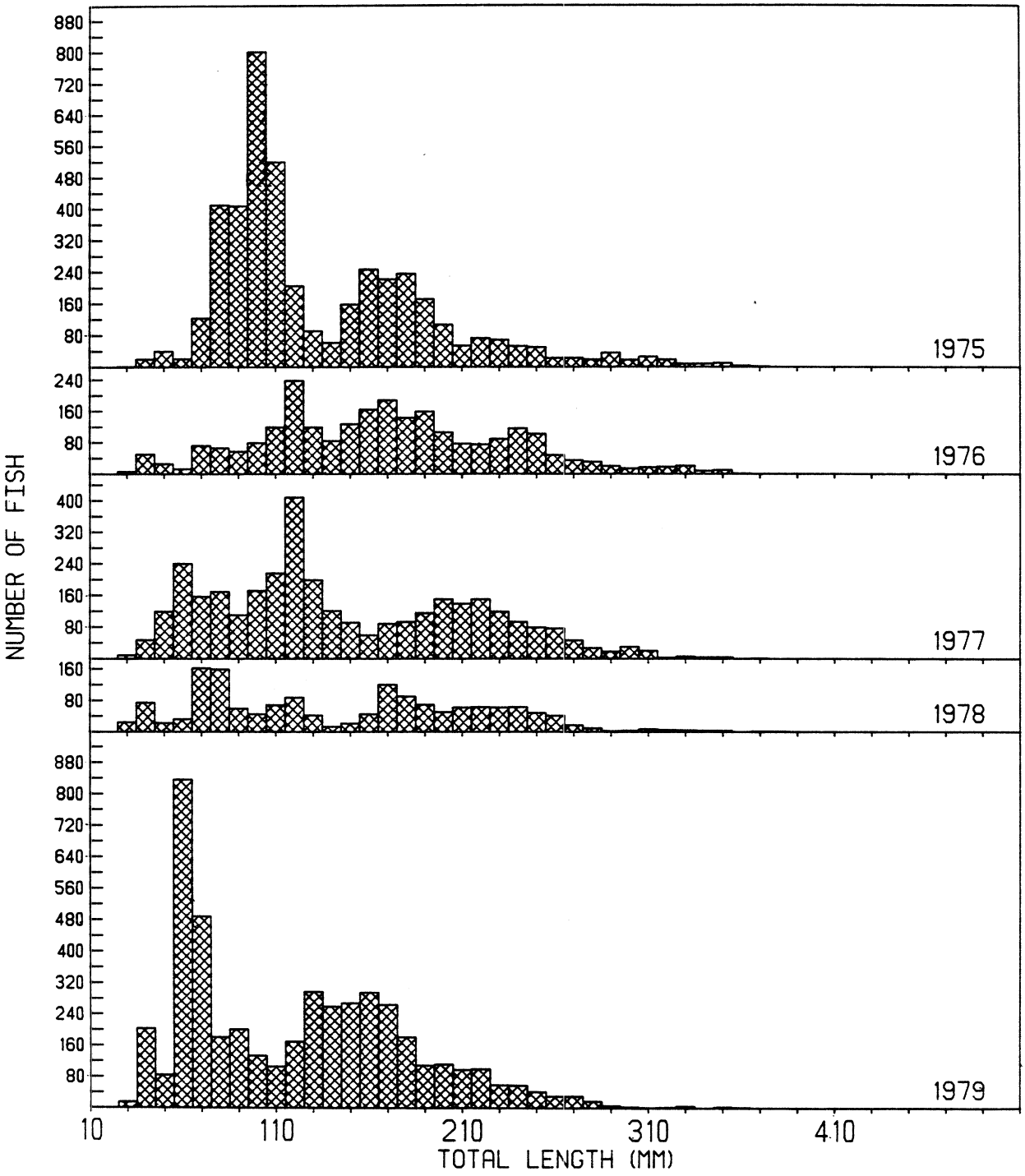
Appendix 68. Length-frequency histograms of spottail shiners impinged from 1975 through 1979 at the Cook Plant, southeastern Lake Michigan.



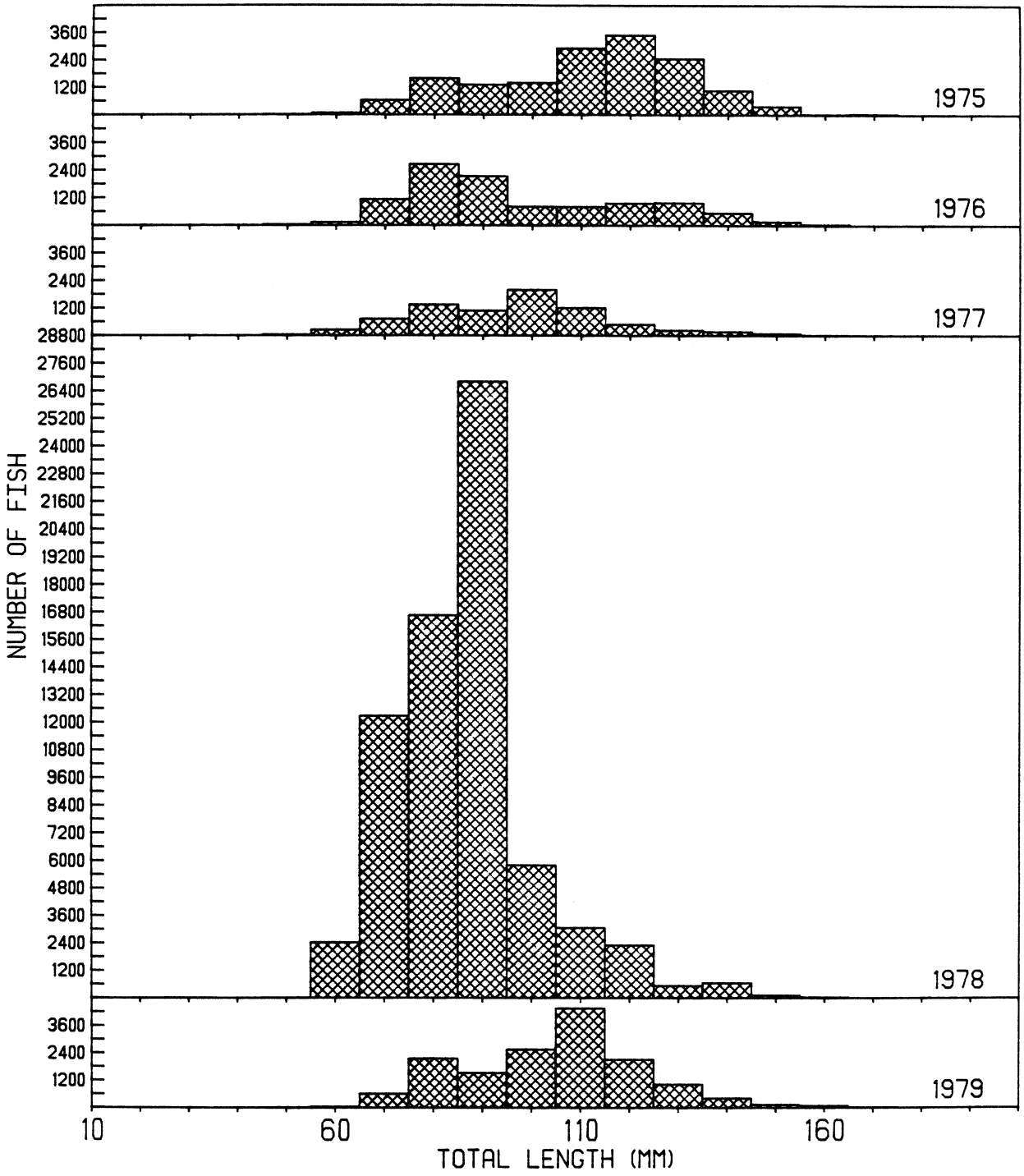
Appendix 69. Length-frequency histograms of spotttail shiners caught during field-sampling from 1975-1979 at the Cook Plant, southeastern Lake Michigan.



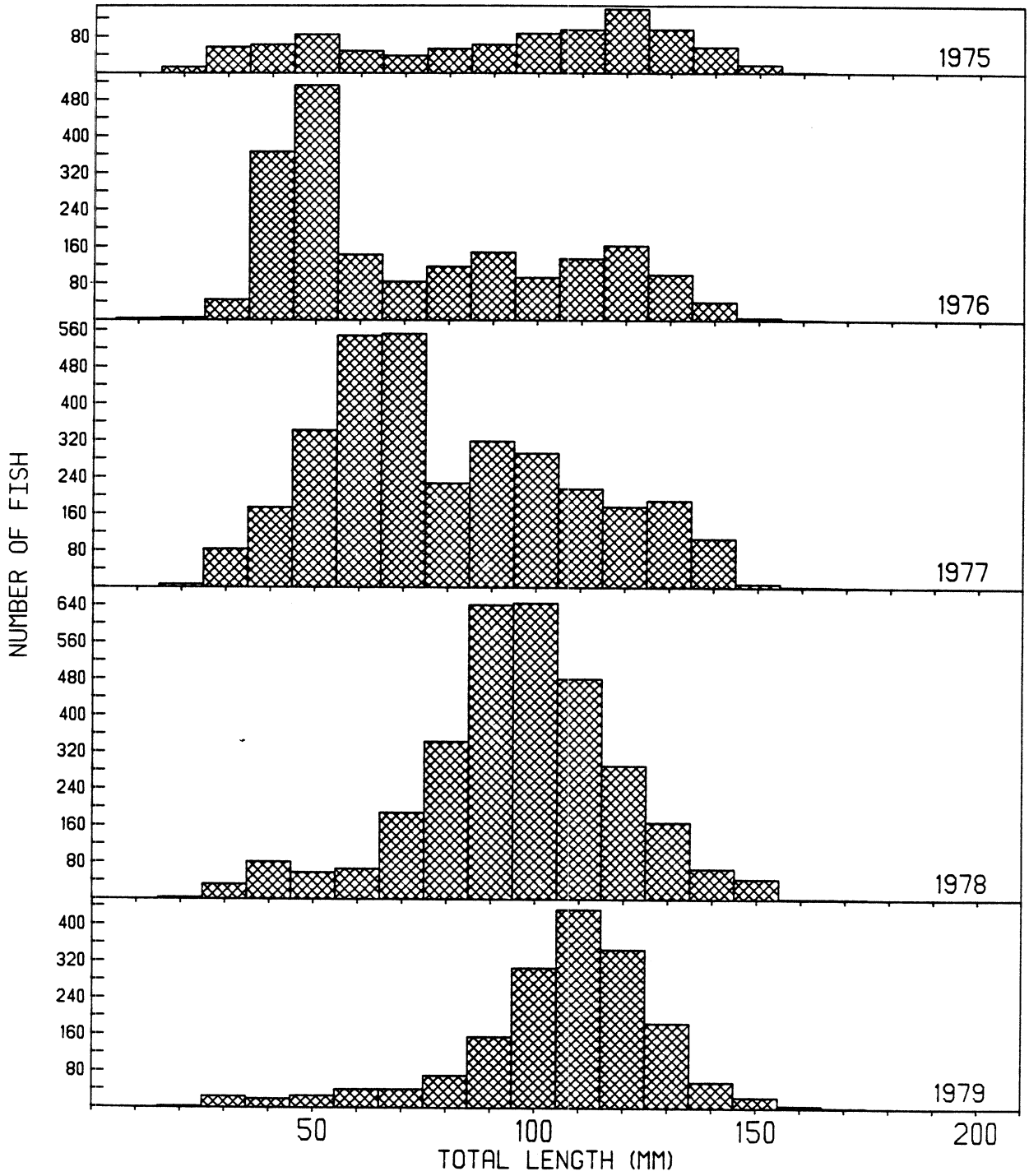
Appendix 70. Length-frequency histograms of yellow perch impinged from 1975 through 1979 at the Cook Plant, southeastern Lake Michigan.



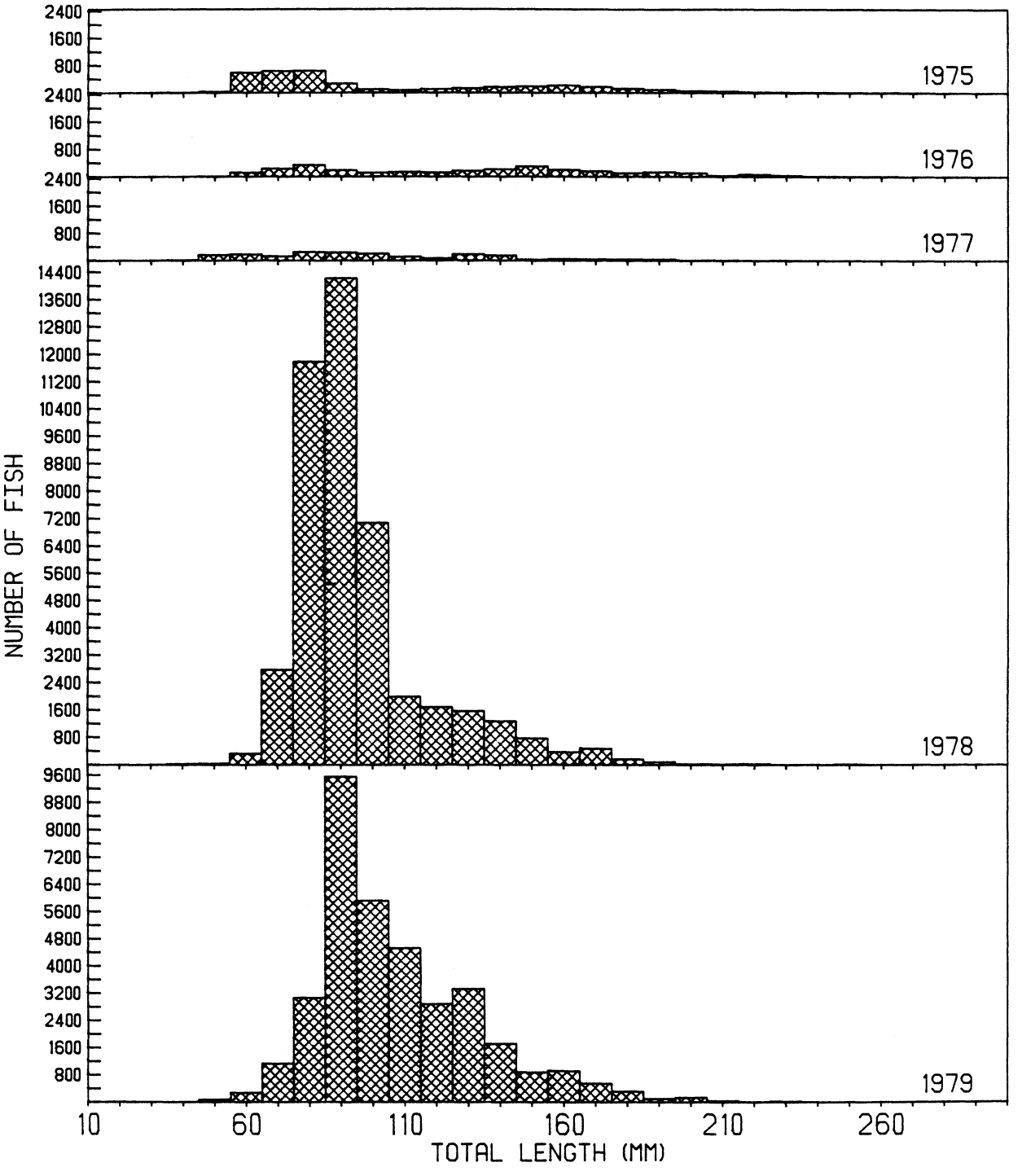
Appendix 71. Length-frequency histograms of yellow perch caught during field-sampling from 1975-1979 at the Cook Plant, southeastern Lake Michigan.



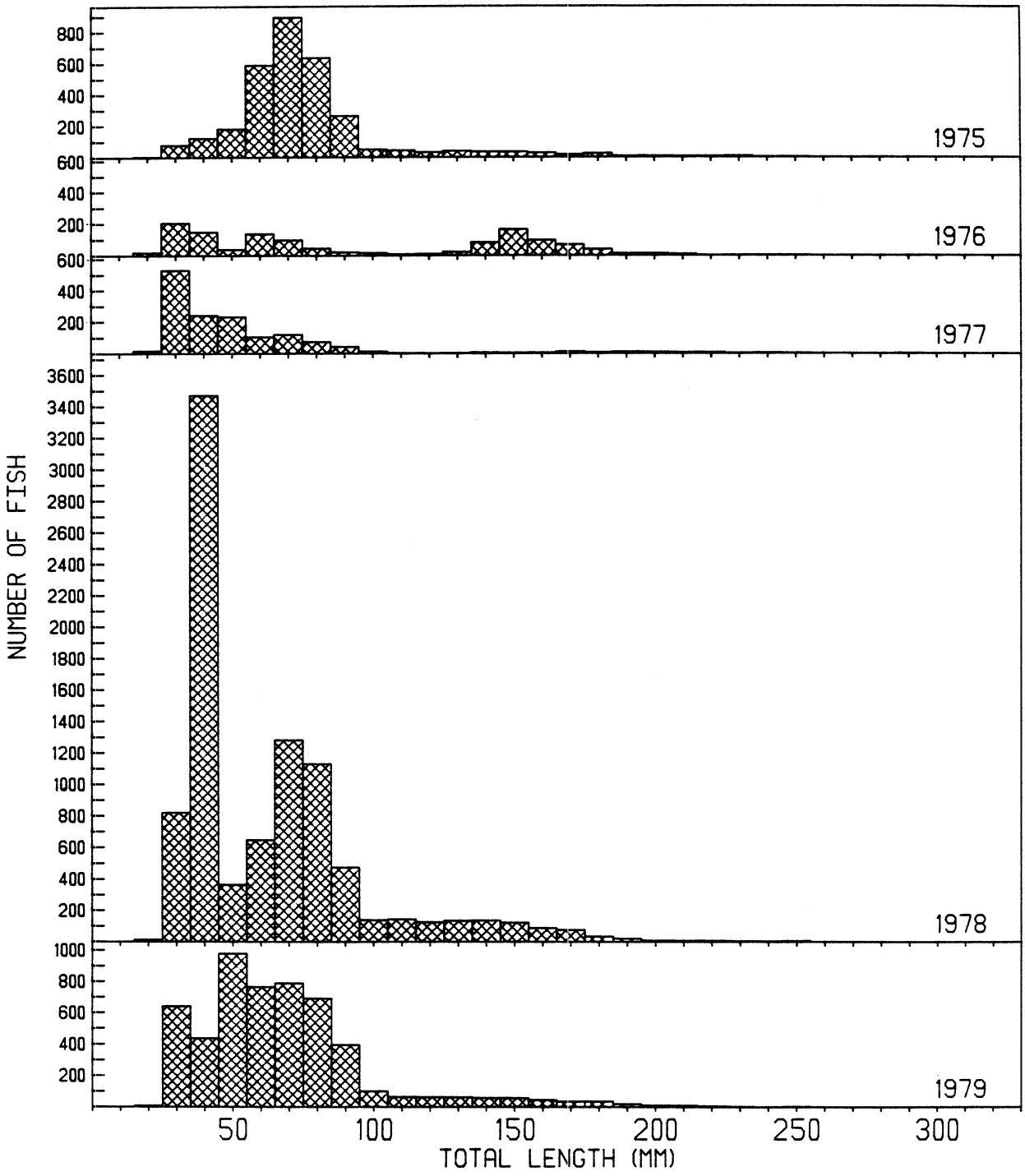
Appendix 72. Length-frequency histograms of trout-perch impinged from 1975 through 1979 at the Cook Plant, southeastern Lake Michigan.



Appendix 73. Length-frequency histograms of trout-perch caught during field-sampling from 1975-1979 at the Cook Plant, southeastern Lake Michigan.



Appendix 74. Length-frequency histograms of rainbow smelt impinged from 1975 through 1979 at the Cook Plant, southeastern Lake Michigan.



Appendix 75. Length-frequency histograms of rainbow smelt caught during field-sampling from 1975-1979 at the Cook Plant, southeastern Lake Michigan.